FACTORS CONTROLLING THE ESTABLISHMENT OF SPECIES-RICH GRASSLANDS IN URBAN LANDSCAPING SCHEMES

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"It has been suggested that ecologists are often the sort of people who work by themselves. In the reconstruction of ecosystems a very different sort of person is necessary. It is patently obvious that the operations require the collaboration of different people, ecologists, engineers, landscape architects and industrialists, and the ability to work with others is essential. But at the same time there is a need for other abilities: to be able to translate theory into practice, and to be able to translate practice, with all its pitfalls and inadequacies, into theory. Sometimes the process is frustrating, perhaps particularly when it demonstrates our ecological inadequacies. But successful reconstruction of ecosystems, when it is achieved, has the reward that it is the ultimate proof of our ecological understanding."

A.D. Bradshaw, 1983

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ABSTRACT

In Britain, the creation of species-rich grasslands has generally involved the use of commercial seed mixtures. The present study has experimented with the use of freshly cut hay as a seed carrying medium and has considered some of the factors thought to be important for the creation of new species-rich grasslands.

Two meadows, established in the early 1980's using hay cut from a single species-rich donor, were surveyed and a high degree of similarity with the donor meadow was noted. It was apparent, however, that the donor meadow had been replicated with a greater level of success by using fresh hay as opposed to dry hay. A total of 41 plant species were recorded in the meadow created using fresh hay, 26 of which may have been introduced as seed from the donor meadow.

The importance of consistent management to sustain diversity was highlighted during the present study. A created meadow which had been poorly managed following its establishment displayed a marked division in its vegetation with large areas dominated by rank grassland species.

Some form of site preparation, other than simply cutting the existing grass sward, favoured a more successful introduction of species from the donor meadow. However, it became clear that high levels of soil cultivation encouraged undesirable weeds and may not be necessary.

Big baling proved to be an efficient method of collecting fresh hay from a donor meadow. It appeared to maximise seed transfer at any one time and a more diverse grassland was created. A meadow created using big baled hay supported a total of 50 plant species in the second year following its seeding, 32 of which were present in the donor sward.

Elevated soil fertility is known to limit plant species diversity in semi-natural and created grasslands. Cropping prior to grassland creation proved to be an effective approach to reducing the effects widely attributed to elevated soil fertility. Although no measurable differences were recorded by chemical analyses, a better species composition and sward structure, and a lower standing crop, were recorded in the created meadows following cropping.

Some crops were more effective at reducing the standing crop of the created sward than others. Potatoes and barley worked particularly well with mean standing crop values for the created sward as low as 335.38g/m^2 in the first year following seeding. In comparison, values of 581.68g/m^2 were recorded in leaching plots which had been cultivated but not cropped and 837.88g/m^2 in control plots in which the original grassland had been retained and which had not been cropped or received hay from the donor meadow.

A novel approach to the use of DECORANA (Hill, 1979b), as presented in the VESPAN software package (Malloch, 1988), proved to be a valuable way of analysing the multivariate species data generated during one cropping experiment. The analysis indicated that, in addition to producing a lower standing crop, cropping with potatoes and barley encouraged a diverse sward to develop which included more species associated with the donor meadow.

Experiments showed that meadow plots created using strewn hay supported a more diverse grassland sward than similar plots created using a purchased seed mixture with mean numbers of species per quadrat recorded of 16.4 and 7.3 respectively in the second year following seeding.

Experiments using different types of donor grassland indicate that the creation of wet grasslands is more problematic than the creation of dry grasslands. In particular created wet grasslands require a longer period in which to become established.

CONTENTS

CHAPTER 1

Introduction

1.0 Introduction

1.1 The Creation of Species-rich Grasslands

The idea of reproducing naturalistic landscapes is not a new one. Wells (1986) points out that more than a century ago Robinson (1870) suggested that certain areas of one's garden might be left unmown so as to encourage `beautiful plants'. Holland has boasted wild flower parks since the late 1920's (Ruff 1979) and habitat restoration in North America has been developing since the mid 1930s when Aldo Leopold and a team of Civilian Conservation Corps workers began replanting tallgrass prairie in Wisconsin (Jordan *et al*, 1987).

In Britain most of the restoration effort was initially centred around the need to re-vegetate areas of derelict land resulting from the activities of the extractive industries (Wells, 1983; Bradshaw & Chadwick, 1980). Research has since been carried out to investigate the potential use of 'habitat creation' to produce diverse plant and animal communities on less difficult land. The extent to which the results of this research are being adopted in practice remains unclear (Hopkins, 1989) although Buckley (1989) suggests that habitat creation is now being used by a range of professions for varied reasons. These reasons include the desire to create visually attractive vegetation, to provide educational and possibly scientific interest, to safeguard rare species or scarce ecological communities and to construct low maintenance landscapes.

Attempts have now been made to create examples of many British ecosystems including simplified examples of even the most fragile such as *Sphagnum* bog (Jones, 1990; Trueman and Lawley, In Prep.). It has been said, however, that for many people habitat creation is synonymous with the grassland creation using wildflower seed (Hopkins, 1989) and research has shown that species-rich grasslands have indeed been the most popular target of habitat creation schemes to date (Jones, 1990).

Almost all British grasslands owe their existence to the activities of man. Nowadays most neutral grasslands (*sensu* Tansley, 1939), which approximate to mesotrophic grasslands (Rodwell, 1992), are totally artificial agricultural swards of recent origin and little conservation importance. However there are still many examples of such grasslands which may be described as semi-natural, being composed of native species but no longer `moulded by nature alone' (Tansley, 1939); these include ancient pastures and meadows which often support diverse assemblages of plants and associated fauna.

The profound effect that differing management has on the species composition of grassland swards has long been known. Tansley (1939) regarded it as even more influential than either climate, soils or the situation of the grassland. In the past, meadows managed by hay cutting and pastures managed by grazing were an important part of the rural economy. Tenancy agreements often contained covenants prohibiting their ploughing-up and some even had their management specified within the law (Mabey, 1980). Consequently the type and method of management used for a particular grassland could be constant for very long periods of time, persisting through several generations, or even centuries, and this man-maintained equilibrium often allowed the development of diverse plant and animal communities.

However, in 1939 fears of food shortages during war time lead the government to introduce a system of grants to encourage the ploughing up of old grassland. Tenancy agreements preventing ploughing were abolished. The ploughing subsidy resulted in a reduction from an estimated pre-war total of 5.2M ha of unimproved lowland grassland, to a post-war total of 3.1M ha, a loss of 40% (Fuller, 1987).

Furthermore, since World War Two agricultural techniques have improved greatly and large areas of permanent and often species-rich grassland, which were once inaccessible to farm machinery, have now been ploughed and improved.

Modern, inorganic fertilisers are widely understood to have an adverse effect on plant species diversity in lowland grass swards (Brenchley, 1958; Elberse *et al*, 1983; Klapp, 1965, Rorison, 1971; Thurston, 1968; Williams, 1978). The addition of fertilisers may be considered as a form of disturbance (*sensu* van Andel & van den Bergh, 1987)[1], and their increased use has been one of the most destructive influences on semi-natural grassland since the war.

The classic experimental work demonstrating the effect of fertiliser applications on grasslands is the Park Grass experiment at Rothamsted Experimental station. Set up in 1856 to investigate the amount and combinations of fertilisers needed to obtain maximum hay yields, this experiment has been continued until the present time. The experimental plot at Rothamsted which remained unfertilised has supported 24 species throughout the study whilst plots treated with ammonium fertilisers, despite originally supporting similar numbers of species to the unfertilised plot, now only support two or three species (Williams, 1978).

The reasons for the reductions in species-richness resulting from fertiliser applications are complex. Manure, which was commonly used to maintain grassland productivity prior to the

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1. Grime (1977) would, of course, distinguish fundamentally between soil enrichment and disturbance.

development of inorganic fertilisers, has a complex chemical and physical structure resulting in the slow release of essential plant nutrients. However, modern fertilisers enable macro-nutrients to be made available for immediate use. A limited number of species, those with a high nutrient demand and rapid growth rate, therefore benefit. The root absorption capacity of these competitive species is high, and at high external nutrient concentrations this provides the minerals necessary for rapid growth (Chapin III, 1980). They become dominant within the grassland to the detriment of other, less competitive, species and sward diversity declines.

However, in addition to direct increases in nutrient availability, decreases in species diversity may also be related to other changes brought about by fertilisation such as decreases in pH (Marrs and Gough, 1989). Furthermore, in terms of the balance of species found on more fertile soils, the relative proportions and amounts of the major nutrients inputted to a system also seems to be important (Marrs & Gough, 1989; Marrs, in press; Digby & Kempton, 1987). Indeed, it is worth remembering that the addition of fertiliser and lime to some naturally floristically-poor grassland communities may contribute to increases in species-diversity as demonstrated by W.E.J. Milton's experiments on the hill pastures at Llety-ifan-Hên in mid-Wales (Jones, 1967; Harper, 1971).

The increase in silage making, involving both a frequent mowing regime and the intensive use of fertiliser, has also made an important contribution to the loss of many species-rich meadows and pastures. Fuller (1987) states that in 1938 most of the grasslands outside the arable rotation received no artificial fertiliser, but that by 1985 85% of all grasslands, including 79% of all permanent grasslands, 85% of all grazings, 93% of all mowings and 99% of all silage areas, had been treated with artificial nitrogen. By 1984, improved grassland had increased to 4.2M ha from a pre-war total of between 0.6M ha and 1.2M ha (Fuller, 1987).

Although the increased use of artificial fertilisers in modern farming systems has been a primary cause of loss of species-rich grasslands in this century, Marrs & Gough (1989) point out that high soil fertility also results from pollutant inputs and the natural accumulation of nutrients during ecological succession. The latter becomes important in grasslands if management regimes are relaxed.

Marrs (in press) defines soil fertility as a function of the combined effects of all ecosystem processes which produce a supply of essential nutrients for plant uptake and suggests that on most sites soil fertility is most likely to be controlled by the three major plant nutrients: nitrogen, phosphorus and potassium. The important relationship between soil fertility and plant species diversity in grasslands is well documented (eg. Bradshaw, 1968; Rorison, 1971) and it is clear that on soils which are not completely limiting in terms of essential plant macro-nutrients such as nitrogen, phosphorus and potassium, diversity generally declines as soil fertility increases.

The British countryside now contains very few examples of grasslands which have never been ploughed and modified. Fuller (1987) calculates that overall 92% of unimproved and rough grassland has now been lost. Those species-rich grasslands which do survive are generally restricted to farmland which remains inaccessible to modern farm machinery, smallholdings and farms managed by farmers maintaining traditional farming methods, some common land, nature reserves and other pockets of relatively undisturbed land such as areas of that owned by the Ministry of Defence. Collectively, however, semi-natural grasslands in lowland Britain support some 550 species which amounts to about a quarter of the total British flora but 81 of these species are now considered to be endangered (Wells & Sheail, 1988).

Those herb-rich meadows and pastures which remain therefore represent a valuable ecological resource and their conservation is nowadays considered to be a priority. Many of the best examples are now designated as Sites of Special Scientific Interest (SSSI) or lie in National Nature Reserves (NNR) and thus receive statutory protection. The massive decline in our species-rich grasslands, which are to many people symbolic of the British rural landscape, is thought to be one of the main reason for their being the focus of the habitat creation effort today (Hopkins, 1989).

The most notable research into the creation of grasslands using commercial seed mixtures has been carried out by the Institute of Terrestrial Ecology at Monks Wood Experimental Station whilst under contract to the Nature Conservancy Council (now English Nature). The findings of this research have been published widely together with information on the collection, storage and germination characteristics of wild flower seed and the propagation of wild flowers for seed production (eg. Wells *et al*, 1981; Wells *et al*, 1986.).

The use of wildflower seed has been popularised in the various habitat creation manuals produced in recent years (eg. Baines & Smart, 1984; Baines, 1985; Emery, 1986; Ash *et al*, 1992), the popular press and gardening magazines (eg. Anon, 1990).

Other approaches to grassland creation have also been investigated. For example, some work has been undertaken in which seed-rich topsoil has been used as a seed source. Wathern and Gilbert (1978) comment briefly on the experimental use of seed-rich topsoil, describing how old meadow soil used to face a dam developed a sward rich in tall herbs and meadow grasses. However, although much has been published describing the seed bank present in soils and the germination characteristics of this seed (eg. Chippendale & Milton, 1934, Champness &

Morris, 1948, Thompson & Grime, 1979, Roberts, 1986, Jefferson & Usher, 1987, Graham & Hutchings, 1988), Wells (1983) suggests that from a practical point of view the use of topsoil is unpredictable, much depending on the soil's origin, the nature of the vegetation growing on it, how it has been stored and the time of year that it was dug.

Other workers have used a habitat translocation approach to reproduce diverse grasslands at a new site (eg. Wathern & Gilbert, 1978; Worthington & Helliwell, 1987; Rawes & Welch, 1972). Recent research commissioned by the Nature Conservancy Council reviews the current experience in this field (Byrne, 1990).

The introduction of pot germinated plants into an established sward has been discussed as an approach to sward diversification (Fenner and Spellerberg 1987). The receptiveness of the surrounding areas to incoming propagules and the availability of suitable regeneration niches (Grubb, 1977) within the existing sward is central to the successful spread of species introduced using this method and as Wells (1983) points out, as an approach to habitat creation, it can prove costly and is therefore usually only applicable to small areas.

Other approaches to the diversification of existing grassland swards have also been used. Slot-seeding, for example, originally developed by the Americans for introducing species into prairies, has been adapted to introduce wildflowers into grassland swards (Wells, 1988). The technique, usually involves the simultaneous spraying of a band of herbicide to kill a strip of the existing turf, the cutting of a slit in the turf and the dropping seed into the slit, carried out in a one-pass operation.

Alternative sources of seed have also been investigated during grassland creation. Wells *et al* (1986) examined the seed content of hay bales from the species-rich meadows and the use of this seed during attempts to establish herb-rich grassland. The seeds of 17 grasses and 24 herbs were identified in the hay bales from North Meadow SSSI at Cricklade, Wiltshire. A total of 28 species were recorded in sown experimental plots by the second season after sowing and 18 of these had originated from the seed in the hay-bales.

The results of these studies suggest that it is possible to create diverse meadows which contain a range of the possibly otherwise unavailable species found in old hay-meadows, using seed contained in hay. Several seed merchants have devised methods for harvesting meadow seed and seed mixtures derived from existing species-rich meadows are available commercially.

An obvious development of the use of seed collected from existing herb-rich grasslands is to harvest the hay crop from such a grassland and spread it over a new site, and in this way introduce the seed of species present in the donor sward. However, little appears in the literature about this as an approach to habitat creation although it has been suggested as a possibility in some publications (Baines and Smart 1984, Emery 1986, Stephens 1988). The successful use of this hay strewing approach has been observed by the director of studies for the current project in Holland.

1.2 Aims of the Present Study

The objectives of the present study were to examine the utility of hay obtained from species-rich meadows in generating new meadows, to investigate some of the factors that are important for the successful establishment of species-rich grasslands and to determine whether or not the conditions present in semi-natural communities causing high diversity can be produced artificially in a relatively short period of time.

In both 1983 and 1984 strewn hay was used by Trueman and Millett in attempts to create diverse meadow vegetation on amenity land owned by Wolverhampton Metropolitan Borough Council (Jones *et al*, in prep.). Chapters 3 and 4 of this report consider the level of success with which the plant community of the donor meadow was reproduced in these two experiments. The donor meadow itself has been surveyed and is described in Chapter 2. This work identified some of the factors important to the success of the hay strewing method as an approach to meadow creation. Some of these factors have been investigated and are described in later chapters.

As soil fertility is critical to grassland diversity (see above), it follows that an important consideration when attempting to create diverse grassland swards is the fertility of the experimental substrate. Cropping experimental sites has been used as a method of lowering soil fertility in Holland, tillage again usually occurring for several seasons before the establishment of diverse plant communities was attempted (Londo, 1977). Marrs (1985) investigated the value of growing crops at Ropers Heath in Suffolk for reducing the high levels of soil nutrients that had accumulated after 25 years of agriculture before attempts were made to restore the former *Calluna vulgaris* dominated heathland.

The value of cropping as an approach to improve the success of meadow creation experiments has been investigated as part of the present study and two experiments are discussed in Chapters 5 and 6 in which different approaches to measuring the success of soil fertility reduction have been used.

Chapter 5 describes an experiment in which potatoes were grown prior to meadow establishment and their value at reducing soil nutrient availability was measured by comparing the species diversity of the created sward with that created in identical but uncropped plots.

In Chapter 6 an experiment is described in which a number of different crops were grown in plots. The level of success of fertility reduction was assessed by determination of the standing crop of a meadow sward created following harvest of the crops.

As sowing commercial seed mixtures remains the most popular approach to grassland creation, an experimental attempt to make a quantitative comparison between this approach and the use of hay strewing was carried out. This experiment is described in Chapter 7.

Finally, as grassland creation has tended to focus on dry mesotrophic swards, attempts were also made during the present study to create damper community types. Chapters 8 and 9 therefore describe attempts to use the hay strewing approach to create a damp meadow community and a damp pasture community respectively.

The experiments described in this report were undertaken as part of a collaborative project between Wolverhampton Polytechnic (now the University of Wolverhampton) and Wolverhampton Metropolitan Borough Council. Since the first meadow was established in Wolverhampton in 1983, around 20 others have been created in the Borough, mostly on land owned by the Council. The majority of these new meadows were initiated during the period 1986 to 1989 by the author and his supervisors, those discussed here therefore represent only a small proportion of the total work undertaken.

Several of the tables presenting experimental data in this report are lengthy. Therefore, to allow continuity in the text, tables and figures have been grouped together at the end of each chapter, and are referenced by both table/figure number and page number.

CHAPTER 2

A Survey of the Vegetation of Pennerley Meadows

2.0 A Survey of the Vegetation of Pennerley Meadows

2.1 Introduction

The hay strewing approach to species-rich grassland creation has been used in Wolverhampton since 1983. The donor site used for the majority of the projects undertaken so far comprises two small (0.8ha), interconnected fields (Grid Reference SO 357991 - field codes 7214 and 6515), situated close to the Stiperstones National Nature Reserve (NNR) in Shropshire.

The Stiperstones lie approximately forty miles due west of Wolverhampton. The upland heathland and moorland vegetation which dominates the Stiperstones is interrupted by small crofts associated with miners cottages and smallholdings. Many have associated areas of grassland, used as paddocks or as a source of hay for winter feed. Although these grasslands are usually unploughed, it is apparent that some in the area have been limed in the past and it is possible, though not proven, that the abundant crystalline calcite in the spoil heaps from the local lead mines may have been used for this purpose (Sinker *et al*, 1985). Many of these grasslands are unimproved and support colourful and botanically diverse swards.

The two small donor fields are examples of such grasslands and have been managed for hay with grazing of the aftermath for an unrecorded length of time. Together with a number of other fields, they were designated as a Site of Special Scientific Interest (SSSI) in 1986. The SSSI is known as Pennerley Meadows SSSI and the two small fields making up the donor meadow will be referred to hereafter in this report as Pennerley Meadows. The donor site is now owned by English Nature who permitted its use for the habitat creation experiments.

Pennerley Meadows were examined as part of the N.C.C. Shropshire Grassland Survey (Welsh, 1982.) and referred to as Association 4(9), but close to Association 5(17), corresponding to the 'Centaureo-Cynosuretum Association, Typical sub-association, variant solitus' and 'Anthoxantho-Festucetum rubrae Association, Typical sub-association' respectively, after Page (1980). The former community type is the characteristic community of "old meadows", and is also found in pastures, churchyards and on roadside verges (Page, 1980). The Association has been found on a wide range of soil types although the soil is often very impoverished with low nitrogen and phosphorus levels. It is a species-rich community, generally forming a fairly low growing sward which has a yellow-green appearance when compared with the bright green colour of improved grassland.

Since Welsh's survey the first volumes of the National Vegetation Classification (NVC)

(Rodwell, 1991 *et seq.*) have been published. Pennerley Meadows have been related to the grassland communities identified by this classification during the present study (see below).

Pennerley Meadows are visually attractive and contain species which have a high aesthetic appeal. Furthermore, grassland creation using this dry meadow as a donor would not be complicated by the need to reproduce complex hydrological regimes. The site was therefore considered to be a suitable donor of hay for grassland creation using the hay strewing approach.

As described in Chapter 1, the first two meadow areas created using this source of hay have been examined as part of the present study. In addition, Pennerley Meadows provided a source of hay and seed for other experiments undertaken during the present study. The grassland sward at the donor site was therefore surveyed in detail.

2.2 Methods

2.2.1 Survey Methods

During the present study all created and donor meadows were surveyed using a systematic approach to ensure good coverage of what could be heterogeneous grassland communities and to allow specific sampling locations to be plotted if required.

The grassland at Pennerley Meadows was surveyed in May/June 1987. A number of temporary transect lines were established and the percentage cover, and thus Domin score (*sensu* Dahl & Hadac, 1941), of each species present was recorded in a 1m x 1m quadrat positioned at regular intervals along each transect line. A total of 111 quadrats were recorded.

During the study, the soil at donor and created meadows was also compared. Ten random soil samples were collected at Pennerley Meadows using an auger (core diameter of 7cm). Samples were taken to a depth of 12cm. The samples collected from Pennerley Meadows were combined and thoroughly mixed before being analysed.

Parameters measured were soil pH, mineral nitrogen (nitrate and ammonium), available phosphorus, available potassium and loss on ignition. Standard analytical methods were used in the chemical analysis (Ministry of Agriculture, Fisheries and Food, 1986) which were undertaken by ADAS soil scientists. Additionally soil texture was determined by 'feel' (Field Handbook of the Soil Survey of Great Britain, 1960).

2.2.2 Data Analysis

Reciprocal Averaging (RA) (Hill, 1973) was used during the analysis of the survey data. RA is an ordination technique, based on eigenanalysis, which has been used widely in the analysis of ecological data, especially since Gauch *et al* (1977) demonstrated its superiority for such applications over previously used techniques such as Principal Components Analysis (Gauch, 1982).

The assumption underlying the analysis is that the distribution of plant species is not random, but that the occurrence of particular species is dependent on the specific physical, chemical, climatic or other environmental conditions associated with the stands of vegetation (quadrats).

The analysis provides both ordinations of stands (placing them in order according to which species they contain) and species (placing them in order according to the stands in which they were recorded). The basis of the ordinations is positive and negative correlation ie. those stands or species which are the most different from one another will be positioned at opposite ends of the ordination.

The ordinated stands or species are distributed along an 'axis of variation' which, in theory, may correspond to an environmental gradient. RA repeats the analysis for progressively less influential axes of variation which, it follows, may correspond to environmental gradients which are sequentially of less importance in terms of species presence and distribution than the first. The results of the analysis are often represented on two dimensional graphs where one axis is plotted against another.

2.3 Results and Discussion

The species recorded at Pennerley Meadows during the botanical survey are listed in a floristic table (Table 2.1: p. 17) following the approach adopted during the compilation of the NVC (Rodwell, 1991 *et seq.*). Species records are divided into five classes based on frequency presented as a percentage. The frequency classes used are:

V	-	81-100% frequency
IV	-	61-80% frequency
III	-	41-60% frequency
II	-	21-40% frequency
I	-	1-20% frequency

The Domin range for each species, i.e. the maximum and minimum Domin score attributed to each species during the survey, is also given in Table 2.1 (p.17).

The meadow soil was light and friable and chemical analysis indicated that it was extremely impoverished in terms of essential plant macro-nutrients (Table 2.2: p. 19). The low soil fertility and apparently consistent management regime used at Pennerley Meadows was reflected by the high plant species diversity. However, Table 2.1 (p. 17) shows that although the Pennerley Meadows sward was diverse, it was dominated by a restricted number of species, predominantly fine grass species such as *Agrostis capillaris*[1], *Festuca rubra*, *Anthoxanthum odoratum*, *Cynosurus cristatus* and *Trisetum flavescens*.

Abundant and characteristic forbs included *Hypochoeris radicata*, *Leucanthemum vulgare*, *Ranunculus bulbosus*, *Rhinanthus minor*, *Trifolium pratense* and *Rumex acetosa*. These species are a conspicuous feature of the meadows during the spring and summer and *L. vulgare* in particular is commonly associated by many with British meadow grasslands and has a high aesthetic appeal.

Pennerley Meadows supported a range of other forb species characteristic of unimproved, mesotrophic grasslands at lower frequency levels, such as *Conopodium majus*, *Primula veris*, *Centaurea nigra*, *Lotus corniculatus* and *Campanula rotundifolia*. Several now uncommon species were also present in the meadow sward, including *Botrychium lunaria*, *Platanthera chlorantha* and *Viola lutea*. These species were once much more abundant in the Stiperstones area before many such grasslands were ploughed.

Direct comparison with the NVC (Rodwell, 1992) indicates that Pennerley Meadows would appear to fall into the *Cynosurus cristatus-Centaurea nigra* Community (code MG5) of that classification system (Table 2.3: p. 20). The sward appears to fit closest to the *Lathyrus pratensis* sub-community but has affinities with all three of the sub-community divisions recognised in the NVC for MG5 grasslands (ie. *Lathyrus pratensis* sub-community, *Galium verum* sub-community and *Danthonia decumbens* sub-community). This may be an indication of slight heterogeneity in the vegetation, and is probably a result of the declining influence of previous (but unrecorded) liming events towards the margins of the meadows. Such a pH gradient could account for the presence of species usually associated with less mesotrophic

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1. Nomenclature follows Clapham, Tutin & Moore, 1987.

conditions. Species such as *Viola lutea* and *Lathyrus montanus* would be at the acidic end of the gradient whilst others, including *Euphrasia officinalis agg.*, *Hieracium pilosella*, *Linum catharticum* and *Platanthera chlorantha*, would be at the opposite end. The return of more acidic conditions at the extreme margins of the meadow is certainly the reason for the occasional presence of heathland species such as *Vaccinium myrtillus*.

Rodwell (1992) describes MG5 grasslands as "the typical grassland of grazed hay-meadows treated in the traditional fashion on circumneutral brown soils throughout the lowlands of Britain". It may be possible that the Pennerley Meadows vegetation represents an unlisted upland variant of MG5 grasslands and the vegetation does have some similarities with the *Anthoxanthum odoratum-Geranium sylvaticum* meadow community (MG3) of the NVC which is described as "an upland grassland [community] confined to areas where traditional hay-meadow treatment has been applied in a harsh sub-montane climate".

The vegetation at Pennerley Meadows has distinct discrepancies with the typical MG5 classification. For example, *Centaurea nigra*, regarded as a constant species (frequency classes V & IV) for MG5 grasslands, does not appear in the list of constant species for Pennerley Meadows. Furthermore, several species typically found at lower frequencies in MG5 grasslands, or absent from this community altogether, were recorded as constant members of the Pennerley Meadows community (eg. *Hieracium pilosella*, *Hypochoeris radicata*, *Leucanthemum vulgare*, *Ranunculus bulbosus*, *Rhinanthus minor* and *Rumex acetosa*). However, experienced NVC recorders have indicated similar findings from supposed MG5 grasslands elsewhere in Britain (Whitfield, pers. comm.).

The high levels of abundance recorded for *Rhinanthus minor* within the Pennerley Meadows sward may be a significant influence on the sward composition. This species is often observed as dense populations (Grime *et al*, 1988) and Rodwell (1992) suggests that severe infestations may greatly reduce the vigour of the grasses and give rise to a sward in which rosette species are dominant. This may account for the higher than typical levels of *Hypochoeris radicata*, *Leucanthemum vulgare* and others within the Pennerley Meadows sward.

The basis for the survey of the vegetation at Pennerley Meadows was to provide botanical data against which created meadows could be compared and the relative success of different created meadows assessed. The group of 'constant species' (frequency class IV and V) recognised at Pennerley Meadows, and their associated mean % cover values, provides a model for this purpose (Table 2.4: p. 22). These data are presented graphically in Figure 2.1 (p. 25). The constant species are the most important members of the sward in terms of determining the character of the vegetation. They are therefore the species which must be established in the correct relative proportions at a new site for meadow creation (replication) to be considered successful. The less frequent members of the community may take longer to establish than the constant species and are unlikely to persist unless the community structure is correct. They therefore represent a less useful model against which to judge the relative success of meadow creation.

In view of the suspected environmental gradients present at Pennerley Meadows, the survey data collected was analysed using the Reciprocal Averaging (RA) ordination technique (Hill, 1973). Axis 1 drawn by the RA species ordination, representing the strongest underlying environmental gradient, produced a cluster of species towards one end of the axis. The remaining species were distributed unevenly on either side of this cluster. *Galium verum* was among the outliers at one end of the axis and *Potentilla erecta*, *Pteridium aquilinum*, *Vaccinium myrtillus* and *Viola lutea* among those at the other end. This may indicate that the weak pH gradient observed at Pennerley is indeed the most important factor producing heterogeneity in the sward.

The species ordination along RA axis 2, the second most influential gradient, also had a range of species lying to either end of the axis. The underlying gradient was more difficult to explain here but the ordination also produced a main cluster of species towards one end of the axis. A plot of the species positions on axis 1 against their positions on axis 2 produces a discrete cluster of species (Figure 2.2: p. 26). These might be considered to be those 'characteristic' of the vegetation type (Table 2.5: p. 23).

A comparison of Tables 2.4 (p. 22) and 2.5 (p. 23) shows that the 'characteristic' species identified by RA includes all of those considered to be 'constant species' within the community, thus supporting the use of these species as a model against which created meadows using this donor site can be assessed. This approach has been used during the assessment of two meadows created in Wolverhampton using hay from Pennerley Meadows, described in Chapters 3 and 4.

TABLES

Table 2.1: Floristic Table for Pennerley Meadows (1987)

Species	a	b
Agrostis capillaris	V	(2-8)
Anthoxanthum odoratum	V	(2-4)
Cynosurus cristatus	V	(1-5)
Dactylis glomerata	V	(1-5)
Festuca rubra	V	(5-9)
Holcus lanatus	V	(1-8)
Hypochoeris radicata	V	(1-4)
Leucanthemum vulgare	V	(1-6)
Plantago lanceolata	V	(2-7)
Ranunculus bulbosus	V	(1-4)
Rhinanthus minor	V	(1-7)
Trifolium pratense	V	(1-6)
Briza media	IV	(1-4)
Hieracium pilosella	IV	(1-5)
Rumex acetosa	IV	(1-5)
Trifolium repens	IV	(1-5)
Trisetum flavescens	IV	(1-5)
Cerastium fontanum	III	(1-3)
Lotus corniculatus	III	(1-5)
Ranunculus acris	III	(1-3)
Conopodium majus	II	(1-3)
Euphrasia officinalis agg.	II	(1-4)
Luzula campestris	II	(1-3)
Veronica chamaedrys	II	(1-3)

Table 2.1. cont.

Species	a	b
Achillea millefolium	I	(3)
Bellis perennis	I	(1-2)
Botrychium lunaria	I	(1-2)
Campanula rotundifolia	I	(1)
Centaurea nigra	I	(1-5)
Galium verum	I	(2)
Heracleum sphondylium	I	(1-4)
Lathyrus montanus	I	(1-3)
L. pratensis	I	(1-3)
Leontodon hispidus	I	(7)
Linum catharticum	I	(1-2)
Lolium perenne	I	(1-4)
Platanthera chlorantha	I	(1)
Potentilla erecta	I	(1-2)
Primula veris	I	(1-6)
Prunella vulgaris	I	(1-2)
Pteridium aquilinum	I	(4)
Rubus fruticosus agg.	I	(1)
Taraxacum spp.	I	(1)
Trifolium dubium	I	(1)
Vaccinium myrtillus	I	(2)
Vicia cracca	I	(1-2)
Viola lutea	I	(3)
V. riviniana	I	(1-3)

Summary	
MEAN NO. OF SPECIES PER QUADRAT	18.6
TOTAL NO. OF STANDS	111
TOTAL NO. OF SPECIES	48

Table 2.2: Analysis of Soils at Pennerley Meadows.

Parameter	
pH	5.7
NO_3 (ppm)	0.1
NH_4 (ppm)	5.1
P (ppm)	5.8
K (ppm)	67.6
% loss on ignition	19.4
texture	silt loam

Table 2.3: Floristic Table for Pennerley Meadows (1987) and a Typical MG5 Grassland

a = frequency class, b = domin range,
c = typical frequency class in MG5 grasslands, d = typical domin range in MG5 grasslands

Species	a	b	c	d
Agrostis capillaris	V	(2-8)	IV	(1-8)
Anthoxanthum odoratum	V	(2-4)	IV	(1-8)
Cynosurus cristatus	V	(1-5)	V	(1-8)
Dactylis glomerata	V	(1-5)	IV	(1-7)
Festuca rubra	V	(5-9)	V	(1-8)
Holcus lanatus	V	(1-8)	IV	(1-6)
Hypochoeris radicata	V	(1-4)	III	(1-5)
Leucanthemum vulgare	V	(1-6)	II	(1-3)
Plantago lanceolata	V	(2-7)	V	(1-7)
Ranunculus bulbosus	V	(1-4)	III	(1-7)
Rhinanthus minor	V	(1-7)	II	(1-5)
Trifolium pratense	V	(1-6)	IV	(1-5)
Briza media	IV	(1-4)	II	(1-6)
Hieracium pilosella	IV	(1-5)		
Rumex acetosa	IV	(1-5)	III	(1-4)
Trifolium repens	IV	(1-5)	IV	(1-9)
Trisetum flavescens	IV	(1-5)	III	(1-6)
Cerastium fontanum	III	(1-3)	II	(1-3)
Lotus corniculatus	III	(1-5)	V	(1-7)
Ranunculus acris	III	(1-3)	III	(1-4)
Conopodium majus	II	(1-3)	I	(1-5)
Euphrasia officinalis agg.	II	(1-4)		
Luzula campestris	II	(1-3)	III	(1-6)
Veronica chamaedrys	II	(1-3)	II	(1-4)

Table 2.3. continued.

Species	a	b	c	d
Achillea millefolium	I	(3)	III	(1-6)
Bellis perennis	I	(1-2)	II	(1-7)
Botrychium lunaria	I	(1-2)		
Campanula rotundifolia	I	(1)		
Centaurea nigra	I	(1-5)	IV	(1-5)
Galium verum	I	(2)	II	(1-6)
Heracleum sphondylium	I	(1-4)	II	(1-5)
Lathyrus montanus	I	(1-3)		
L. pratensis	I	(1-3)	II	(1-5)
Leontodon hispidus	I	(7)	II	(1-6)
Linum catharticum	I	(1-2)		
Lolium perenne	I	(1-4)	III	(1-8)
Platanthera chlorantha	I	(1)		
Potentilla erecta	I	(1-2)	I	(1-4)
Primula veris	I	(1-6)	II	(1-4)
Prunella vulgaris	I	(1-2)	III	(1-4)
Pteridium aquilinum	I	(4)		
Rubus fruticosus agg.	I	(1)		
Taraxacum spp.	I	(1)	III	(1-4)
Trifolium dubium	I	(1)	II	(1-8)
Vaccinium myrtillus	I	(2)		
Vicia cracca	I	(1-2)	I	(1-4)
Viola lutea	I	(3)		
V. riviniana	I	(1-3)		

Table 2.4: Constant Species within the Pennerley Meadows Community.

a = frequency class, b = domin range, c = mean % cover value.

Species	a	b	c
Agrostis capillaris	V	(2-8)	18.44
Anthoxanthum odoratum	V	(2-4)	3.47
Cynosurus cristatus	V	(1-5)	2.33
Dactylis glomerata	V	(1-5)	4.72
Festuca rubra	V	(5-9)	46.12
Holcus lanatus	V	(1-8)	12.60
Hypochoeris radicata	V	(1-4)	2.15
Leucanthemum vulgare	V	(1-6)	9.86
Plantago lanceolata	V	(2-7)	12.96
Ranunculus bulbosus	V	(1-4)	3.04
Rhinanthus minor	V	(1-7)	11.93
Trifolium pratense	V	(1-6)	6.55
Briza media	IV	(1-4)	1.40
Hieracium pilosella	IV	(1-5)	2.17
Rumex acetosa	IV	(1-5)	1.82
Trifolium repens	IV	(1-5)	2.23
Trisetum flavescens	IV	(1-5)	3.12

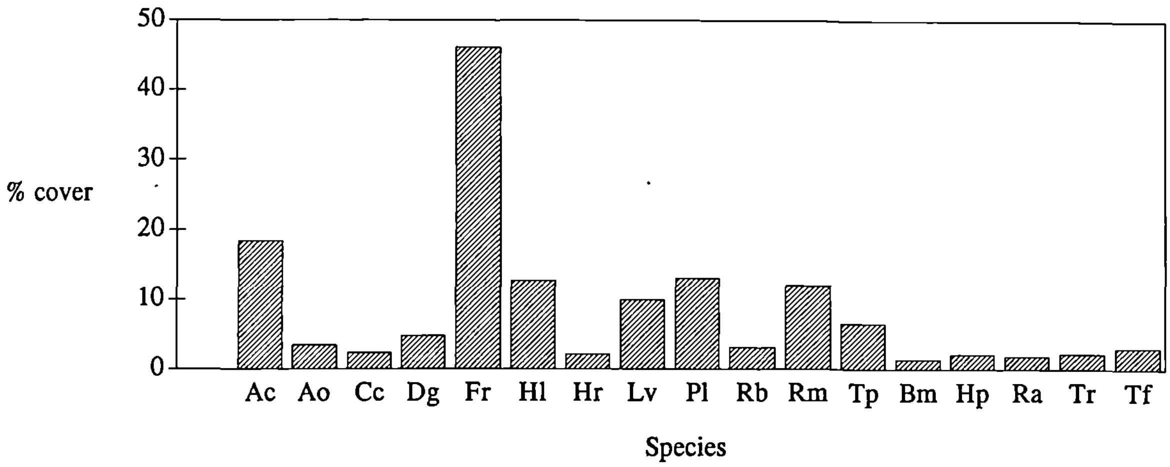
Table 2.5: Species 'Characteristic' of the Pennerley Meadows Community Identified by Reciprocal Averaging Ordination.

a = frequency class, b = domin range.

Species	a	b
Agrostis capillaris	V	(2-8)
Anthoxanthum odoratum	V	(2-4)
Cynosurus cristatus	V	(1-5)
Dactylis glomerata	V	(1-5)
Festuca rubra	V	(5-9)
Holcus lanatus	V	(1-8)
Hypochoeris radicata	V	(1-4)
Leucanthemum vulgare	V	(1-6)
Plantago lanceolata	V	(2-7)
Ranunculus bulbosus	V	(1-4)
Rhinanthus minor	V	(1-7)
Trifolium pratense	V	(1-6)
Briza media	IV	(1-4)
Hieracium pilosella	IV	(1-5)
Rumex acetosa	IV	(1-5)
Trifolium repens	IV	(1-5)
Trisetum flavescens	IV	(1-5)
Ranunculus acris	III	(1-3)
Euphrasia officinalis agg.	II	(1-4)
Luzula campestris	II	(1-3)
Veronica chamaedrys	II	(1-3)
Achillea millefolium	I	(3)
Lathyrus montanus	I	(1-3)
L. pratensis	I	(1-3)
Leontodon hispidus	I	(7)
Linum catharticum	I	(1-2)
Platanthera chlorantha	I	(1)
Primula veris	I	(1-6)

FIGURES

Figure 2.1: Histogram Showing Mean % Cover of Constant Species at Pennerley Meadows (1987).

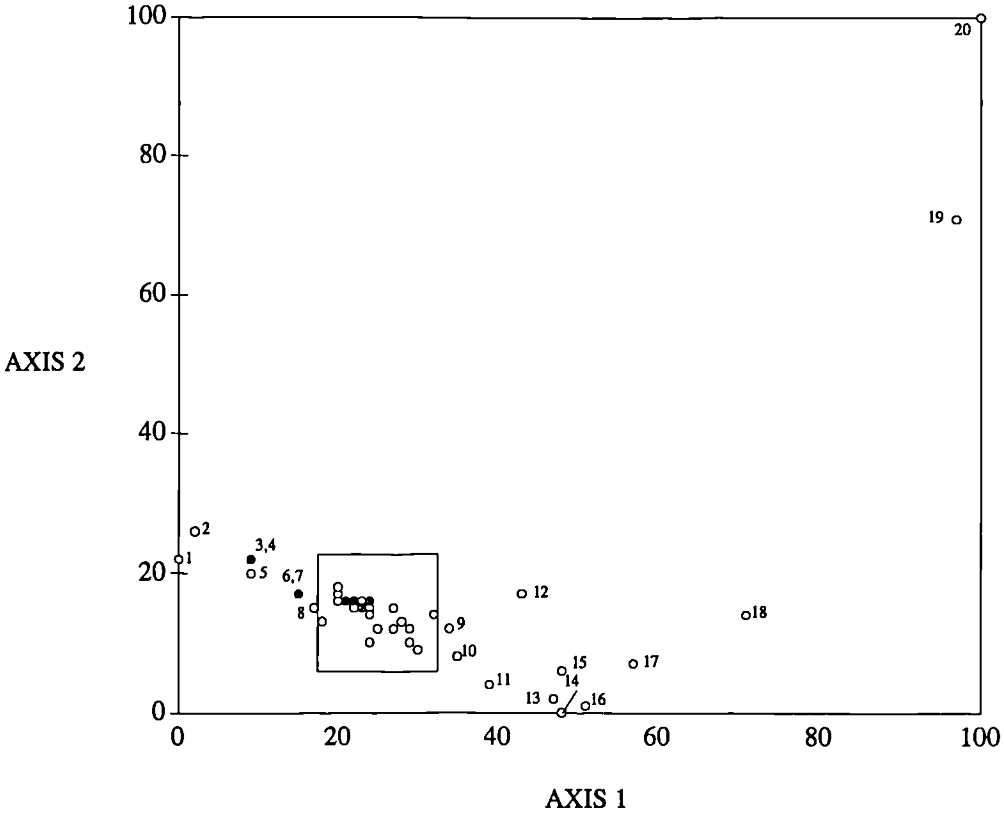


CONSTANT SPECIES

Agrostis capillaris (Ac)
Anthoxanthum odoratum (Ao)
Cynosurus cristatus (Cc)
Dactylis glomerata (Dg)
Festuca rubra (Fr)
Holcus lanatus (Hl)
Hypochoeris radicata (Hr)
Leucnthemum vulgare (Lv)
Plantago lanceolata (Pl)
Ranunculus bulbosus (Rb)
Rhinanthus minor (Rm)
Trifolium pratense (Tp)
Briza media (Bm)
Hieracium pilosella (Hp)
Rumex acetosa (Ra)
Trifolium repens (Tr)
Trisetum flavescens (Tf)

Figure 2.2: A Plot of Axis 1 Against Axis 2 of the Reciprocal Averaging Species Ordination for Pennerley Meadows Showing the Cluster of 'Characteristic Species'.

(o= single species •= multiple species)



SPECIES IN CLUSTER LISTED IN TABLE 2.5

SPECIES OUTSIDE CLUSTER:

1. Lolium perenne
2. Taraxacum spp.
3. Bellis perennis
4. Heracleum sphondylium
5. Galium verum
6. Cerastium fontanum
7. Conopodium majus
8. Primula veris
9. Lotus corniculatus
10. Campanula rotundifolia
11. Trifolium dubium
12. Vicia cracca
13. Viola lutea
14. Rubus fruticosus agg.
15. Vaccinium myrtillus
16. Centaurea nigra
17. Viola riviniana
18. Botrychium lunaria
19. Potentilla erecta
20. Pteridium aquilinum

CHAPTER 3

Changes in the Vegetation of Peasley Wood Meadow

3.0 Changes in the Vegetation of Peasley Wood Meadow

3.1 Introduction

Peasley Wood (SO 872982) is a mix of plantation and secondary woodland in an old, long disused sand quarry in the west of Wolverhampton. On the borders of the wood, adjacent to the Staffordshire and Worcestershire Canal, is an area of dry, level ground which, prior to 1982, supported wasteland/rank grassland dominated by *Chamaenerion angustifolium* with abundant *Arrhenatherum elatius*, *Rubus fruticosus agg.*, *Dactylis glomerata* and *Stellaria graminea*. The whole woodland site is owned by Wolverhampton Metropolitan Borough Council and the wasteland area was made available in 1982 for the first attempt at meadow creation undertaken in Wolverhampton.

The creation of a meadow at Peasley Wood was initiated in the autumn of 1982. An experimental area measuring approximately $1800m^2$ was delimited in the wasteland adjacent to the wood, cleared of vegetation and cultivated by hand. Cultivation was repeated in June 1983 and as much rhizomatous material was removed from the experimental area as possible. A Manpower Services team from the local branch of the Friends of the Earth provided the workforce. No form of experimental variation in treatment was attempted during this initial attempt at meadow creation.

Field 7214 at Pennerley Meadows (c. 0.4ha) (see Chapter 2) was cut for hay on 12 July 1983. As part of the negotiated use of the donor meadow on this occasion the hay was allowed to dry for one week after being cut, during which period there was no rain and the swathes were turned once by hand. The amount of seed 'lost' from the hay during this period is unknown but it is likely that it was high. After the drying period the hay was raked into piles and transported in a covered van to the Peasley Wood site, where it was spread evenly over the whole experimental area. The hay was allowed to dry further until September 1983, after which it was raked together and removed from the site.

Since its establishment, the created meadow has been managed by a single annual cut. The time of cut has varied according to the weather, but has never been earlier than August. Cutting has involved a combination of Allen Scythe and sickles except in 1986, when it was delayed until December and a 'brush-cutter' was used. In 1988, as a result of improved access to the site via a new gate connecting it with a neighbouring school, the hay crop was cut using a tractor drawn rotary-mower and the extent of the cut area was also very much increased. Cut material has always been removed from the experimental area immediately with no attempt to make hay.

As part of the present study the meadow was surveyed and the results of the survey compared with those of the survey undertaken at the donor site in order to assess to what degree the replication of the Pennerley Meadow vegetation had been successful.

3.2 Methods

3.2.1 Survey Methods

A systematic survey was carried out at the Peasley Wood meadow during June 1987. Temporary transect lines were established and the percentage cover of each species present was estimated within a 1m x 1m quadrat positioned at regular intervals along each transect line. A total 60 quadrats were recorded. This was equivalent to the number of quadrats recorded during a survey carried out at the Peasley Wood meadow in 1984 under the direction of the Director of Studies for the present study. The results of the first survey were available.

Five soil samples were also collected from the meadow for comparison with the analysis of soil samples taken from Pennerley Meadows. An auger with a core diameter of 7cm was used and cores were taken to a depth of 12cm. Each soil sample was made up of several random cores which were combined and thoroughly mixed. The soil samples were analysed for pH, nitrogen as nitrate and ammonium, available phosphorus, available potassium and loss on ignition. Standard analytical methods were used in the chemical analysis (Ministry of Agriculture, Fisheries and Food, 1986). Additionally soil texture was determined by 'feel' (Field Handbook of the Soil Survey of Great Britain, 1960).

3.2.2 Data Analysis

Simple indications of the degree of similarity of the donor and created meadow were obtained using the Sørensen index:

$$\text{Sørensen coefficient (ISs)} = (2c/A + B) \times 100$$

where:

A = the total number of species at site 1
B = the total number of species at site 2
c = the number of species common to both sites

The index is designed to equal 100 in cases of complete similarity (ie. where the two sets of species are identical) and 0 if the sites are completely dissimilar, having no species in common. The index has its limitations as it takes no account of the relative abundance of the species so that all species count equally in the equation irrespective of whether they are abundant or rare. However, it is a useful and widely used index (Magurran, 1988) and provides an indication of the similarity of two sites in terms of the species present which, for the present study, is a valuable initial indication of grassland creation success.

Indicator Species Analysis (ISA) (Hill *et al*, 1975) was also used during the analysis of the survey data from the Peasley Wood meadow. ISA is a divisive classification technique ie. all samples are initially clustered together and successively divided into a hierarchy of smaller and smaller clusters (Gauch, 1982). Divisive methods are said to have an advantage over agglomerative ones (ie. where clusters are gradually built up from the individual elements) in that they use all available information at the initial stage of the analysis and are "less likely to be irrevocably led astray by chance" (Noy-Meir, 1973). ISA also has the advantage of being a polythetic method, where divisions are based on many attributes (cf. monothetic methods where at each step only a single attribute is used) so that all the available information is used during the analysis.

During ISA the data set is first ordinated by reciprocal averaging although, unlike RA (Hill, 1973 - see Chapter 2), the analysis is based on stand ordination only. Each stage of the analysis involves only the axis which corresponds to the most important gradient. The axis is divided at a point corresponding to the mean of the ordination scores for all the stands present, known as its 'centre of gravity'. The two groups of stands formed by the division are labelled using binary notation ie. the initial division produces groups 0 and 1. Groups 0 and 1 are then subjected to ordination separately and the centre of gravity of each is determined, thus forming groups 00, 01, 10 and 11. The analysis is continued until a pre-determined number of divisions have been made.

At each division, indicator species for the groups formed are identified, being determined according to their relative occurrence in the two groups on either side of a centre of gravity. The indicator value (I_j) of any species (j) is defined mathematically as:

$$I_j = m1/M1 - m2/M2$$

where m1 is the number of occurrences of species j in any one group which contains M1 stands and m2 is the occurrence of species j in the group on the other side of the division which contains M2 stands.

The results of ISA are often displayed on a dendrogram which shows schematically the divisions produced by the analysis, the numbers of stands in each group and the indicator species identified.

3.3 Results

A summary of the results of the surveys of the created meadow at Peasley Wood carried out in 1984 and 1987 is presented in Table 3.1 (p. 38), together with the results of the survey of Pennerley Meadows, using the same format adopted in Chapter 2.

After the introduction of seed in the hay from Pennerley Meadows, a dense grass-dominated sward established at the experimental area at Peasley Wood in a relatively short period of time. When the new meadow was surveyed in 1984 survey, 26 species were recorded, 17 of which are members of the Pennerley Meadows community and may have been introduced as seed with the hay. It is clear from Table 3.1 (p. 38) that most of the fine grasses and forbs which are constant members of the Pennerley Meadows sward had become established in the created meadow by 1984, some at frequencies comparable to the donor meadow.

Few species recorded at frequencies lower than 60% (frequency classes III, II & I) in the Pennerley Meadows sward were noted during the 1984 survey of Peasley Wood meadow. However, nine species were recorded in the new meadow which were not present at Pennerley Meadows. Most of these 'additional' species were probably present at the experimental site prior to meadow creation. Indeed, the most abundant additional species, *Chamaenerion angustifolium*, was dominant on the site prior to the experiment. This species thrives on recently cleared sites where its short-lived but numerous seeds frequently approach 'saturating densities' (Grime *et al*, 1988). Although its seeds are not incorporated into a persistent seed bank, many would have been present at the site as a result of flowering in the season preceding site preparation. *C. angustifolium* can also regenerate from rhizomatous material although most of this was removed during site preparation.

By 1987 the number of species present in the created meadow had increased to 36 species, 27 of which were present at Pennerley Meadows. A Sørensen coefficient calculated to compare Pennerley Meadows and the Peasley Wood meadow indicates that the degree of similarity between the two sites had increased in terms of all of the species present between 1984 and 1987 (Table 3.2: p. 40). However, Table 3.1 (p. 38) shows that although the total number of species present in the experimental area had increased, the number of species present in the created sward which were recorded at Pennerley Meadows at frequencies less than 60% remained low and the mean number of species recorded per quadrat had decreased since the earlier survey.

It became clear during the 1987 survey that there was a high degree of heterogeneity within the created sward. An area of short and moderately diverse vegetation in the centre of the experimental area, containing a range of species found in the Pennerley Meadows sward, was surrounded by taller and coarser vegetation towards the margins. The frequency of several of the fine grasses present in 1984 had declined by 1987 whilst *Dactylis glomerata* had increase dramatically in terms of both frequency and abundance.

Table 3.1 (p. 38) shows that, despite the encroachment of coarse grass species, a range of species were successfully introduced from the donor meadow and had become established by 1987. It is also clear, however, that most of these species were not present in the created meadow at the frequencies and levels of abundance recorded at the donor meadow.

As described in Chapter 2, the mean percentage cover of the constant species at Pennerley Meadows may be used as a model against which the success of habitat creation can be assessed (see Table 3.3: p. 41 and Figure 3.1: p. 44). Table 3.3 (p. 41) and Figure 3.1 (p. 44) show that, of the constant species, *Holcus lanatus* was by far the most abundant in the created sward in 1984. This is probably a reflection of high quantities of seed of this species retained in the dry hay from Pennerley Meadows and also the plant's highly efficient abilities to colonise open habitats (Grime *et al*, 1988). In addition, it is likely that seed of this species, which is persistent, was present in the seed bank at the experimental site and germinated following the removal of the original vegetation.

By 1987 *H.lanatus* had declined to levels of frequency and abundance that were lower than those recorded for the species in the donor meadow. *Dactylis glomerata*, on the other hand, had increased to become the dominant species.

D. glomerata is a frequent but not an abundant member of the Pennerley Meadows sward. In the absence of management this species forms tussocks and is a vigorous competitor with other plant species and these characteristics were noted in the created meadow in 1987. The increasing levels of abundance of this and other coarse species characteristic of neglect and poor management such as *Arrhenatherum elatius*, and *Rubus fruticosus agg.* (Table 3.1: p. 38) in the created sward, suggest that the management of the created meadow following its establishment had not been adequate. The areas of coarse vegetation had characteristics of the MG1 *Arrhenatherum elatius* community of the NVC (Rodwell, 1992), with affinities with several of the sub-communities in this classification. Rodwell (1992) suggests that this grassland community occurs in neglected agricultural land such as badly-managed pastures and meadows.

The decline of *H. lanatus* between 1984 and 1987 may be a reflection of the increased competition from the coarser grasses resulting from the poor management of the created meadow. The height at which a sward is cut has a marked effect upon the ability of this species to propagate from seed (Watt, 1978). Hart and McGuire (1964) found that at increased summer cutting heights, light becomes a major limiting factor to the establishment of this species in the following spring.

However, Renison (1976) found that, due to its aggressive root competition, *H. lanatus* has a greater competitive ability than *Dactylis glomerata* when the two species are grown in a 50:50 mixture and the species does form a persistent seed bank (Roberts, 1986). It is therefore possible that the introduction of a more appropriate management regime to the created meadow would also produce an increase in the abundance of *H. lanatus*. As this species is a strong competitor with other grassland species, such an increase may be as detrimental in terms of the diversity of the created sward as the encroachment of *Dactylis glomerata*.

Table 3.3 (p. 41) also shows that *Festuca rubra* and *Agrostis capillaris*, which form a major component of the vegetation at Pennerley Meadows, were introduced to the experimental site and their mean percentage covers increased between 1984 and 1987. However, by 1987 both species were still less abundant within the created meadows than at the donor site, again probably a result of poor management and the consequential competition of more vigorous coarse grass species. Furthermore, the abundance of several of the other fine grass species constant in the Pennerley Meadows sward, such as *Anthoxanthum odoratum* and *Cynosurus cristatus*, declined in the created sward between 1984 and 1987, probably also a result of high competition.

In addition to a coarser sward, one of the most noticeable visual differences from Pennerley Meadows was the limited amounts of *Leucanthemum vulgare* and *Hypochoeris radicata*. The lower abundance of these and other visually characteristic and constant species of the donor sward, such as *Ranunculus bulbosus*, *Rhinanthus minor*, *Rumex acetosa* and *Trifolium pratense*, at the created meadow (Table 3.3: p. 41) meant that the created meadow did not, on the whole, have the visual characteristics and aesthetic appeal of the donor meadow.

Indicator Species Analyses (ISA) confirmed that it was possible to delimit two distinct types of vegetation at the Peasley Wood meadow in both 1984 and 1987, one of which was dominated by coarse species, the other containing the species associated with Pennerley Meadows.

ISA for the 1984 data (Figure 3.2: p. 45) placed 23 stands, containing the coarser vegetation type, into group 1 with indicator species including *Dactylis glomerata*, *Galium aparine* and *Urtica dioica*. Group 0 contained the remaining 37 stands with *Agrostis capillaris*, *Lotus corniculatus* and *Trisetum flavescens* being among the indicator species.

The ISA of the data collected during 1987 indicates that the number of stands containing the finer vegetation resembling Pennerley Meadows had decreased to 24 with a corresponding increase in rank grassland stands to 36 (Figure 3.3: p. 46).

These results suggest that after a reasonably successful transfer of seed and meadow establishment, there has been an encroachment of rank grassland species from the margins of the experimental plot, and a gradual diminution of the area occupied by the created vegetation. This decrease in the area covered by the vegetation resembling Pennerley Meadows was despite the overall increase in the similarity of the Peasley Wood meadow to donor site in terms of the species present indicated by the Sørensen coefficient.

Analysis of the soil of the experimental area at Peasley Wood (Table 3.4: p. 42) indicated that although it is slightly more fertile than that at Pennerley Meadows, particularly with respect to the levels of potassium, the levels of macro-nutrients are significantly lower than those of a typical productive British soil (Bradshaw & Chadwick, 1980). It is unlikely, therefore, that the differences between the created vegetation and the donor meadow are primarily related to differences in soil conditions.

3.4 Discussion

It is clear that the success of the Peasley Wood meadow was only limited and that, after the first season, the sward began to deteriorate due to poor management. The reasons for the limited initial success may relate to a number of factors, not least the use of dry hay as the seed-carrying medium.

As outlined in the introduction to this chapter, the negotiated use of the hay from Pennerley Meadows for this initial experiment required that it be allowed to dry for a week at the donor site prior to its transfer to the experimental site. Although most of the seed of hay-meadow species is timed for release prior to the main hay cut, a large amount of seed remains unshed and is retained in the hay during the cutting operation. However, the drying period, together with the usual turning of the hay, provides a second opportunity for seed to reach the soil. It is likely that a great deal of the seed retained in the Pennerley Meadows hay was lost during the week that its was allowed to dry following cutting. Although it is unclear to what degree this may effect the different species in terms of the relative amounts of seed retained after the drying period, it seems feasible that smaller seeds are more likely to be lost from the hay than larger seeds. This may be another reason for the abundance of *Holcus lanatus* in the created meadow during its first season as this species has a relatively large seed with a short bristle on the attached lemma (Grime *et al*, 1988).

In view of the high seed losses during a drying period away from the experimental site and the potential disproportionate representation of meadow species in dried hay, all meadows created in Wolverhampton subsequent to the Peasley Wood meadow involved the use of green, undried hay.

As suggested above, the deterioration in the created sward after its establishment, in particular the encroachment of coarse *Dactylis glomerata* dominated vegetation, may be attributed mainly to the poor management used. The importance of management and its effects on vegetation have been known for a long time and have been the subject of long-term experimentation (Brenchley, 1958). Even minor imperfections in the management of a grassland, particularly one which has only recently been established, can have profound effects on the balance of species in the vegetation. For recently created grasslands there are likely to be many opportunities for the management to vary from the ideal. The Peasley Wood meadow site was practically inaccessible to machinery prior to 1988. As a result, management was restricted to an annual cut using hand held machinery; a significant change from the cutting and aftermath grazing management used at Pennerley.

The mechanisms whereby changes in management will produce changes in the vegetation are not particularly obscure. In meadow creation, the import of fresh hay is simply a method of introducing species to the seed bank of a new site. Many of the introduced species may flower and set seed within a short time period, whilst others will remain within the seed bank and will germinate if conditions become suitable. Suitable conditions may be brought about coincidentally by management.

The regeneration of species that are already established is also assisted by management practices. Although vegetative regeneration plays an important part in the dispersal of species within a grassland and the ultimate composition of the community, for many species the rate of vegetative spread is slow and regeneration by seed is the only feasible method of invading neighbouring areas.

Successful species establishment from seed in grasslands is dependent not only the production of sufficient quantities of viable seed and efficient methods of seed dispersal, but also on the availability of suitable regeneration gaps (*sensu* Grubb, 1977) for germination and subsequent establishment.

The dry hay-meadow community at Pennerley Meadows contains many species which may be considered as moderately opportunistic. *Leucanthemum vulgare* for example, has a wide-ranging distribution but one that is centred on vegetation associated with intermediate levels of disturbance (Grime *et al*, 1988). Wells (pers comm.) regards *L. vulgare* as an important or characteristic species during the early stages of development of some created meadows on heavy soils with a high clay content, but one that is replaced within a few years. Similarly *Hypochoeris radicata*, another characteristic species at Pennerley Meadows is also described as a species most often found in conditions of moderate disturbance (Grime *et al*, 1988).

The fact that these and other species that have a distribution centred on slightly disturbed environments are abundant at Pennerley Meadows, despite a management regime that has been consistent over many decades, suggests that traditional hay-meadow management is a harsh form of disturbance which produces the necessary regeneration gaps for such species to persist in the grassland sward. This may be particularly true for hay-meadows on light sandy soils such as those of the Stiperstones.

The annual cycle of hay-meadow management is rigorous. The vegetation is cut as short as possible, and the ground is both disturbed and compacted by the various stages of hay making. The process takes place in a period deliberately chosen to be dry, and the exposed stubble generally becomes scorched and crushed. When the vegetation finally starts to recover grazing animals are introduced. Not only is foliage removed but plants are trampled and the soil may be disturbed or poached. The accumulative affect of these many forms of incidental disturbance is to provide a variety of regeneration gaps to be exploited.

This emphasises the great importance of introducing an adequately harsh management regime to newly constructed meadows supporting such species so as to encourage a sustainable community that is capable of diversification. The resemblance between the processes taking place in a well managed meadow and a single cut with immediate removal of hay as used at the Peasley Wood meadow is approximate in the extreme. It is not clear whether the detrimental changes to the created sward caused by the lack of suitable management in the early stages of its development are reversible although it is unlikely that such changes can be reversed in the short-term by simply introducing an improved management regime.

TABLES

Table 3.1: Floristic Table for Pennerley Meadows (1987) and Peasley Wood Meadow (1984 & 1987).

a = frequency class, b = domin range.

	PENNERLEY		PEASLEY WOOD			
			1984		1987	
Species	a	b	a	b	a	b
Agrostis capillaris	V	(2-8)	II	(1-4)	III	(2-6)
Anthoxanthum odoratum	V	(2-4)	V	(1-3)	II	(1-3)
Cynosurus cristatus	V	(1-5)	V	(1-3)	I	(1-2)
Dactylis glomerata	V	(1-5)	I	(1-2)	V	(3-10)
Festuca rubra	V	(5-9)	V	(1-5)	V	(3-9)
Holcus lanatus	V	(1-8)	V	(6-10)	II	(2-7)
Hypochoeris radicata	V	(1-4)	IV	(1-3)	I	(1)
Leucanthemum vulgare	V	(1-6)	I	(1)	I	(1-5)
Plantago lanceolata	V	(2-7)	IV	(1-5)	II	(1-5)
Ranunculus bulbosus	V	(1-4)	IV	(1-3)	I	(1-3)
Rhinanthus minor	V	(1-7)	III	(1-3)	IV	(1-6)
Trifolium pratense	V	(1-6)			II	(1-4)
Briza media	IV	(1-4)				
Hieracium pilosella	IV	(1-5)				
Rumex acetosa	IV	(1-5)			II	(1-4)
Trifolium repens	IV	(1-5)	IV	(1-3)	I	(1-2)
Trisetum flavescens	IV	(1-5)	IV	(1-3)	IV	(2-7)
Cerastium fontanum	III	(1-3)	II	(1-3)	I	(1-2)
Lotus corniculatus	III	(1-5)	I	(1-2)	I	(1-4)
Ranunculus acris	III	(1-3)				
Conopodium majus	II	(1-3)			I	(1-3)
Euphrasia officinalis agg.	II	(1-4)				
Luzula campestris	II	(1-3)			II	(1-3)
Veronica chamaedrys	II	(1-3)			I	(1)

Table 3.1 continued.

Species	PENNERLEY		PEASLEY WOOD			
			1984		1987	
	a	b	a	b	a	b
Achillea millefolium	I	(3)				
Bellis perennis	I	(1-2)				
Botrychium lunaria	I	(1-2)				
Campanula rotundifolia	I	(1)				
Centaurea nigra	I	(1-5)			I	(2)
Galium verum	I	(2)				
Heracleum sphondylium	I	(1-4)			I	(1-5)
Lathyrus montanus	I	(1-3)				
L. pratensis	I	(1-3)			II	(1-4)
Leontodon hispidus	I	(7)			I	(1)
Linum catharticum	I	(1-2)				
Lolium perenne	I	(1-4)			I	(2)
Platanthera chlorantha	I	(1)				
Potentilla erecta	I	(1-2)				
Primula veris	I	(1-6)				
Prunella vulgaris	I	(1-2)				
Pteridium aquilinum	I	(4)				
Rubus fruticosus agg.	I	(1)	I	(1-7)	II	(1-5)
Taraxacum spp.	I	(1)				
Trifolium dubium	I	(1)				
Vaccinium myrtillus	I	(2)				
Vicia cracca	I	(1-2)	I	(1-3)	I	(1-3)
Viola lutea	I	(3)				
V. riviniana	I	(1-3)				
Arrhenatherum elatius			I	(2-3)	II	(2-8)
Chamaenerion angustifolium			V	(1-6)	IV	(1-4)
Dryopteris filix-mas					I	(1)
Elymus repens			II	(1-3)		
Equisetum arvense					I	(3)
Galium aparine			II	(1-4)	I	(2-3)
Holcus mollis					I	(2)
Leontodon autumnalis			I	(1)		
Poa pratensis			I	(1)		
P. trivialis			I	(1-2)		
Ranunculus repens			I	(1-2)	I	(1-2)
Stellaria graminea					II	(1-3)
Urtica dioica			I	(1)	I	(1-2)

Summary	PENNERLEY	PEASLEY WOOD	
		1984	1987
mean no. species/quadrat	18.6	11.5	8.9
total no. of stands	111	60	60
total no. of species	48	26	36

Table 3.2: Comparison of Peasley Wood Meadow (1984 & 1987) with Pennerley Meadows (1987) Using the Sørensen Index of Similarity (ISs).

YEAR	ISs
1984	45.9%
1987	64.3%

Table 3.3: Frequency and Abundance of Pennerley Meadows Constant Species in the Created Meadow at Peasley Wood

a = frequency class, b = domin range, c = mean % cover value.

Species	1984 a	1984 b	1984 c	1987 a	1987 b	1987 c
Agrostis capillaris	II	(1-4)	0.70	III	(2-6)	4.48
Anthoxanthum odoratum	V	(1-3)	1.75	II	(1-3)	0.82
Cynosurus cristatus	V	(1-3)	1.92	I	(1-2)	0.05
Dactylis glomerata	I	(1-2)	0.13	V	(3-10)	48.68
Festuca rubra	V	(1-5)	3.00	V	(3-9)	35.04
Holcus lanatus	V	(6-10)	69.93	II	(2-7)	3.27
Hypochoeris radicata	IV	(1-3)	0.98	I	(1)	0.02
Leucanthemum vulgare	I	(1)	0.13	I	(1-5)	0.90
Plantago lanceolata	IV	(1-5)	1.47	II	(1-5)	1.67
Ranunculus bulbosus	IV	(1-3)	1.03	I	(1-3)	0.18
Rhinanthus minor	III	(1-3)	0.92	IV	(1-6)	3.29
Trifolium pratense	---	---	---	II	(1-4)	0.47
Briza media	---	---	---	---	---	---
Hieracium pilosella	---	---	---	---	---	---
Rumex acetosa	---	---	---	II	(1-4)	0.67
Trifolium repens	IV	(1-3)	1.03	I	(1-2)	0.15
Trisetum flavescens	IV	(1-3)	1.30	IV	(2-7)	6.83

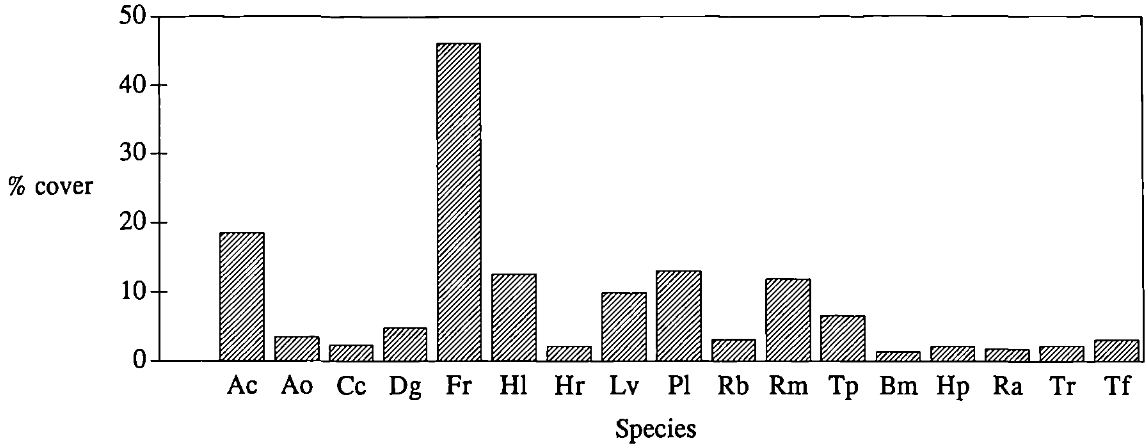
Table 3.4: Analysis of Soils at Peasley Wood Meadow (1987)

Parameter	
pH	5.3
NO_3 (ppm)	1.5
NH_4 (ppm)	3.4
P (ppm)	7.4
K (ppm)	109.4
% loss on ignition	11.1
texture	sandy loam

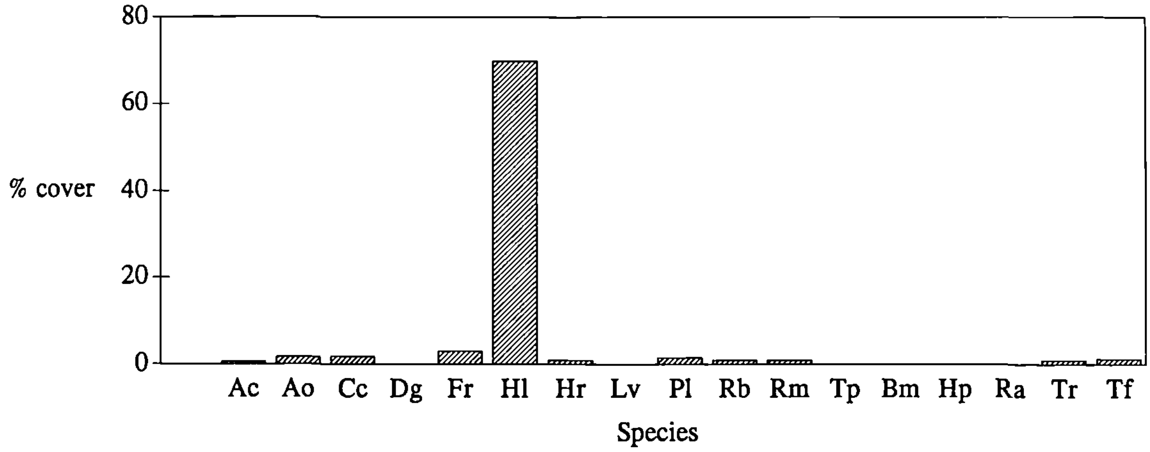
FIGURES

Figure 3.1: Histogram Showing Mean % Cover of Constant Species at Pennerley Meadows and Peasley Wood.

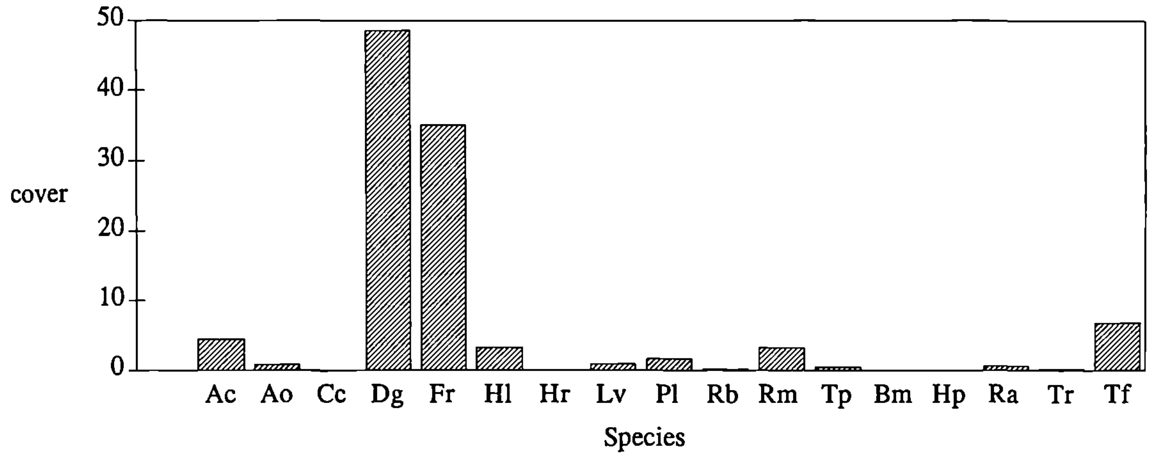
- PENNERLEY MEADOWS (1987)



- PEASLEY WOOD (1984)



- PEASLEY WOOD (1987)



NOTE: Abreviations are used for species names; species are given in the same order as shown in Table 3.3.

Figure 3.2: Dendrogram to Illustrate the First Division of the Indicator Species Analysis for the Peasley Wood Meadow (1984).

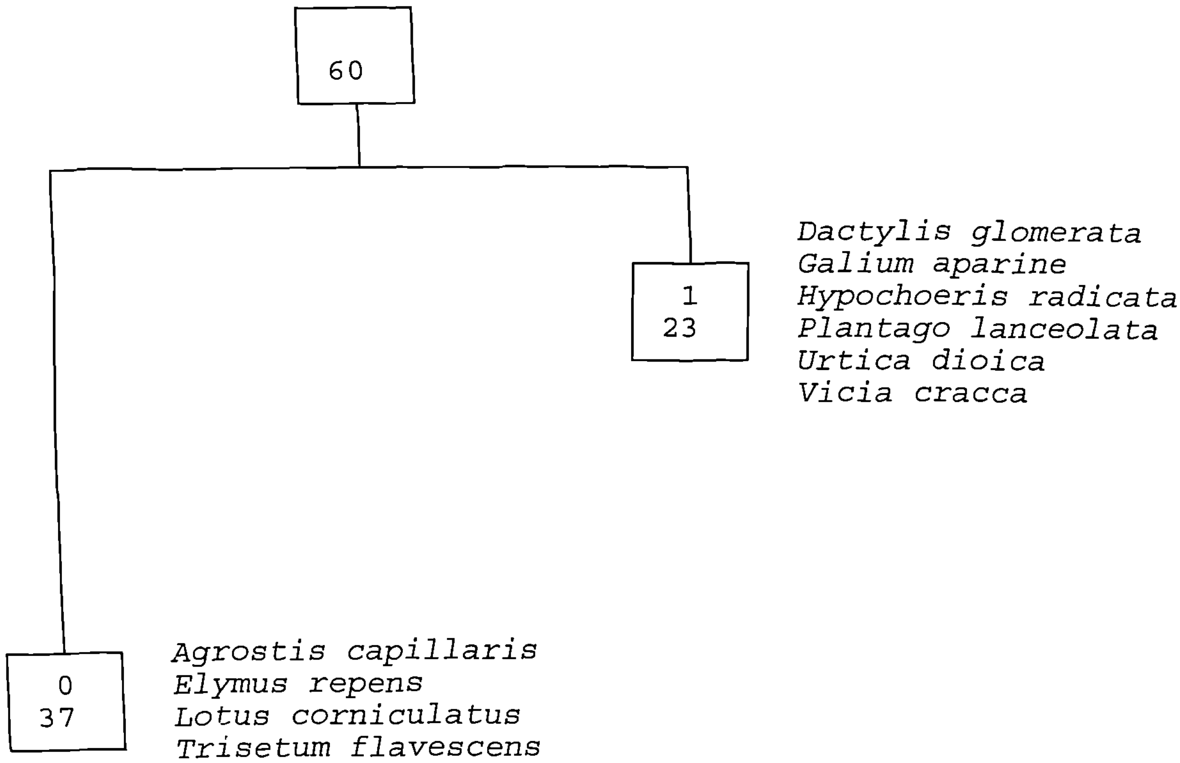
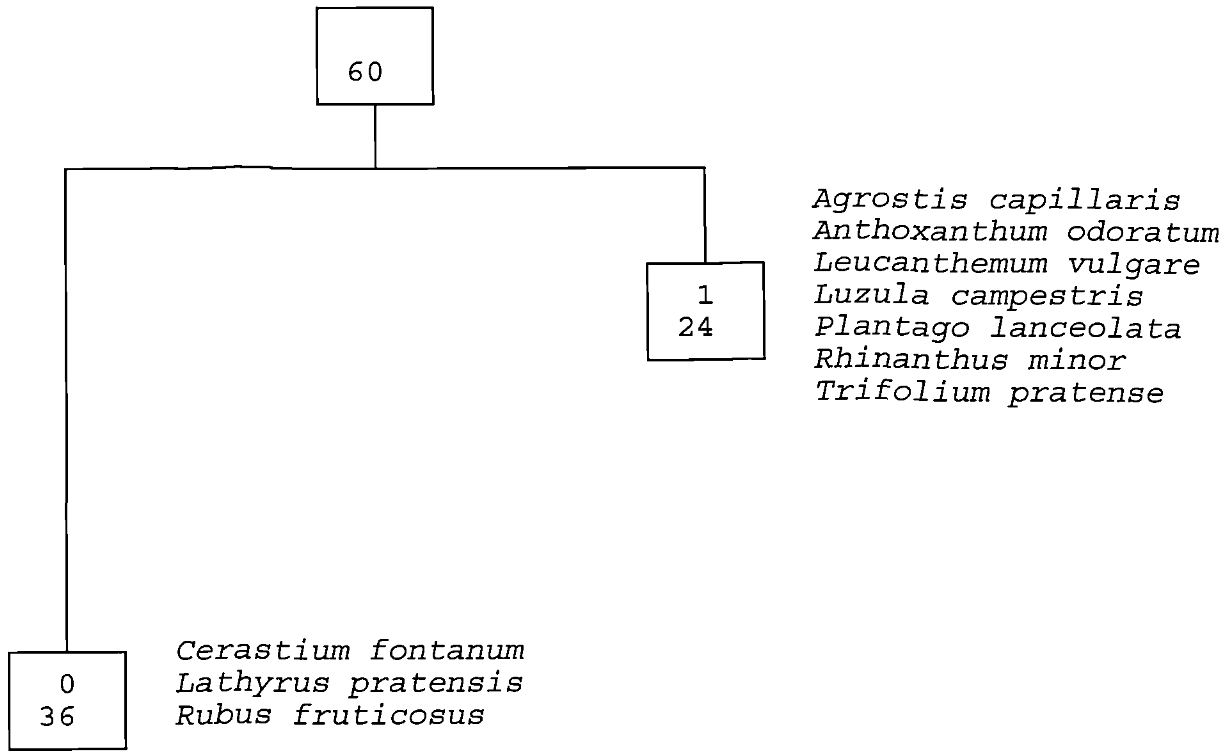


Figure 3.3: Dendrogram to Illustrate the First Division of the Indicator Species Analysis for the Peasley Wood Meadow (1987).



CHAPTER 4

Assessment of a Created Meadow at Bushbury Hill

4.0 Assessment of a Created Meadow at Bushbury Hill

4.1 Introduction

Bushbury Hill (SJ 926022) lies in the north of Wolverhampton. The gentle, north-west facing slopes of the hill are maintained as urban open space with extensive areas of amenity grassland and small plantations of trees and shrubs. The use of the area as amenity land dates back to the early 1960's when a municipal refuse tip in a former sand quarry on the hill was reclaimed. Although the specific details of the reclamation are unclear, it is apparent that a relatively nutrient-poor, light topsoil was imported and spread to cover the clay cap of the tip. No record remains of the amenity seed mixture used to establish the grassland.

Prior to the meadow creation experiment described in this chapter, all of the grassland on the hill was maintained by gang mowing every two weeks. There is some suggestion that when it was first established a less frequent regime was used to maintain the grassland, the sward being cut two or three times a year with a tractor mounted flail-mower. The grass cuttings have never been removed from the site.

The slope and aspect of the amenity land on Bushbury Hill are similar to those at Pennerley Meadows, although the altitude is somewhat lower, and in 1984 an area was made available by the local authority for a second attempt at meadow creation using strewn hay from the Shropshire donor site.

The experimental area was approximately 2670m^2 in extent and located towards the top of the hill so that the majority of the amenity grassland remained undisturbed. It was bordered on three sides by areas of tree and shrub planting and on the fourth by amenity grassland.

Site preparation began in June 1984 and was undertaken by employees of the Parks Department of Wolverhampton MBC under the supervision of the Director of Studies and Second Supervisor for the present study. The Parks Department's own equipment was used.

The experimental area was divided into five plots in which various approaches to site preparation, involving combinations of cultivation and herbicide treatments, were tested. No form of replication was attempted.

The treatments used were as follows:

Plot 1 - amenity sward rotovated only.
Plot 2 - amenity sward killed using glyphosate and rotovated after seven days.
Plot 3 - amenity sward killed using glyphosate but not rotovated.
Plot 4 - amenity sward cut and retained.
Control -amenity grassland retained and no strewn hay.

A schematic plan of the experimental area is given in Figure 4.1 (p. 71).

Field 7214 at Pennerley was cut for hay on the 19 July 1984. The hay was not allowed to dry as previously (Chapter 3) and on 20 July 1984 it was raked together by hand and transported loose on a lorry to the experimental site. Half of the hay, the product of approximately 2000m^2 of hay-meadow, was spread evenly over plots 1 to 4 at Bushbury Hill. The control plot did not receive hay.

The ratio of the area of donor meadow supplying hay (2000m^2) to experimental area was approximately 1:1.14. The productivity of the donor meadow is low and consequently only a small amount of hay was actually imported and spread over the experimental area. No attempt was made to remove the hay from the experimental plots when it had dried as the small amount spread was considered insufficient to impede seedling growth.

The management used at the site since its establishment has been somewhat inconsistent. The new meadow was first cut in August 1985 using a tractor mounted flail-mower and raked off after several weeks. It was then not cut again until February 1987 when a 'brush cutter' was used and the cut vegetation raked off immediately. The hay was cut again on the 28 July 1987 using a tractor mounted flail mower and raked off on the following day. Since 1987 a more regular cutting regime has been introduced as part of the overall management of the open space. Cutting takes place in July/August and the hay is removed.

The meadow was surveyed in 1987 as part of the present study in order to assess the degree to which the meadow community at Pennerley Meadows had been reproduced and to determine which approach to site preparation had been the most successful.

4.2 Methods

4.2.1 Survey Methods

A systematic survey of the Bushbury Hill meadow was carried out in June 1987. Transect lines were run across each of the plots and the percentage cover of the species present recorded in 1m x 1m quadrats positioned at 2m intervals along each line. A total of 106 quadrats were recorded, 12 quadrats in the control plot, 21 in plot 1, 25 in plots 2 and 3 and 23 in plot 4.

A number of random soil samples were also taken in each of the plots. Samples were taken to a depth of 12cm using an auger with a core diameter of 7cm. The random samples collected in each plot were combined and thoroughly mixed before being analysed. Parameters measured were pH, nitrate, ammonium, available phosphorus, available potassium and loss on ignition. Standard analytical methods were used (Ministry of Agriculture, Fisheries and Food, 1986). An assessment of soil texture was also made using the approach developed by the Soil Survey of Great Britain (1960).

4.2.2 Analytical Methods

During the analysis of the survey data Reciprocal Averaging (RA) (Hill, 1973) and Indicator Species Analysis (ISA) (Hill *et al*, 1975) were used. The nature of these analyses has been described in Chapters 2 and 3 respectively.

4.3 Results

By 1987 a closed meadow sward had developed at Bushbury Hill. The grassland was colourful, visually attractive and, despite a taller and more productive sward, bore some resemblance to the donor meadow. A summary of the survey results for the meadow (excluding the control plot) is presented in Table 4.1 (p. 61).

Overall, 41 species were recorded in the experimental plots, 26 of which may have been introduced in the hay from Pennerley Meadows. All of the high frequency 'constant' species in the donor meadow sward, with the exception of *Hieracium pilosella*, were established in the created meadow by the time of the survey, many at comparable levels of frequency and abundance. Overall the sward was dominated by *Festuca rubra* and *Holcus lanatus*, although forbs such as *Leucanthemum vulgare*, *Ranunculus bulbosus* and *Rhinanthus minor* were abundant and provided the main visual similarity with the donor.

The list of species present at lower frequencies in the donor meadow which failed to transfer to the new site is long but shorter than that for Peasley Wood. Several of these less frequent species eg. *Cerastium fontanum*, *Bellis perennis* and *Lolium perenne* are, however, common grassland species and it is possible that they had survived from the original amenity sward rather than been introduced in the hay. They were present in the control plot.

Centaurea nigra was very infrequent at Peasley Wood in 1987 but had become better established at Bushbury Hill where it was recorded at frequencies and levels of abundance comparable with those recorded at the donor meadow.

Many of the lower frequency species which were not recorded during the survey of the created meadow, such as *Botrychium lunaria*, *Linum catharticum* and *Platanthera chlorantha*, are indicative of old, well established grasslands and unlikely to transfer easily.

The absence of *Hieracium pilosella* in the created sward, despite being a community constant at Pennerley Meadows, is also likely to relate to its habitat requirements. The distribution of this species is centred on unproductive, grazed habitats as it is vulnerable to the shade of taller plants. Furthermore it is excluded completely by high levels of disturbance (Grime *et al*, 1988). Its presence at frequencies greater than 60% at Pennerley Meadows was one of the main discrepancies of the donor vegetation from typical MG5 grasslands. However the extremely low productivity and low stature of the donor sward, and probably the effects of historic liming, seem to favour this species. By contrast, at the new Bushbury Hill meadow the species would have found high levels of disturbance as a result of site preparation and intense competition from species taller than itself - conditions under which it cannot compete - hence its absence.

It is possible that *Hieracium pilosella* will appear in the Bushbury Hill meadow in time. However, although other species whose distribution is centred on relatively undisturbed habitats are beginning to make an appearance (eg. *Briza media* and *Primula veris* [see below]), *H. pilosella* does not form a permanent seed bank and it is unlikely that any seed introduced with the hay will survive until conditions become suitable.

Despite the complete absence of *Hieracium pilosella*, the main difference between the created and donor meadows in terms of the constant species was the low frequency of *Agrostis capillaris*. This species is co-dominant in the donor sward along with *Festuca rubra*, and together they form the basic grass matrix in which the other species grow. Its virtual absence from the created meadow is therefore of some concern, particularly as it was present at even lower frequencies than noted in the earlier experiment at Peasley Wood (Chapter 3).

Although *A. capillaris* is most frequent in vegetation of intermediate to low productivity, and subject to moderate or low intensities of disturbance (Grime *et al*, 1988), it is generally ubiquitous and found in a wide range of situations. There is apparently no reason why it should be so infrequent in the created meadow other than a failure to introduce seed. It flowers between June and August (Hubbard, 1984) and it is therefore conceivable that at Pennerley Meadows seeds are not mature by the time of the main hay cut, particularly as its primary regenerative strategy in grasslands is by means of rhizomes which afford it the ability for rapid lateral spread. If this is the case then only a limited amount of seed would have been present in the hay transported to the experimental sites.

In the few quadrats at Bushbury Hill in which it was recorded during the surveys, *A. capillaris* had attained moderate levels of abundance demonstrating that if introduced it has the ability to survive and spread at this site. It is obviously one of the casualties of the transfer of hay from a single cut during the hay strewing experiments at Peasley Wood and Bushbury Hill. It is possible that a phased cutting and transfer of hay from the donor meadow may have allowed a more successful introduction of *A. capillaris* to the experimental site.

Phased cutting of the donor meadow may also improve the chances of transfer of other, lower frequency species from the donor sward which failed to become established at the experimental site. If cut earlier, for example, the hay may well have contained seed of *Luzula campestris*, whilst a later cut could have increased the chances of transferring *Campanula rotundifolia* to the new site.

The lack of seed in the hay was not, however, the reason for the absence of *Primula veris* at the new meadow. Although *P. veris* commences growth in winter and flowers in spring, seeds of this species were abundant in the hay transported to the Bushbury Hill site. Despite this the plant failed to establish at the new site in the first few years after seeding. Observations suggest that this species readily becomes established in seed-mix based meadow creation schemes.

P. veris was observed for the first time at the Bushbury Hill meadow in 1989 and it has thrived subsequently (despite the unfortunate removal of plants by members of the public). It seems possible therefore that the absence of this species during the early years relates, not to a failure to introduce seed, but to its requirement for relatively undisturbed soil conditions and inability to compete in tall vegetation. It seems that it is only when a new meadow 'settles down' that it starts to flourish.

A further difference between the created meadow and the donor sward relates to the nature of the clovers present, particularly *Trifolium pratense*. Table 4.1 (p. 61) indicates that this species and *T. repens* were present at frequencies and levels of abundance comparable to the donor meadow. However, during the surveys it was clear that the size and vigour of individual plants was noticeably different at the two sites. These nitrogen-fixing species thrive, and often demonstrate such characteristics, in soil low in nitrogen but with moderate to high levels of phosphorus. However, the soil analysis carried out indicated that low nitrogen levels at Bushbury Hill were accompanied by mean levels of phosphorus that were also quite low and not too dissimilar to the donor meadow (Table 4.2: p. 64). This suggests that there are other reasons for the vigorous growth of clovers at this site. It may be possible that the high level of soil disturbance during site preparation favoured these species although there is also some indication that these species grow particularly well after a harsh winter, as grass growth in the early part of the season is suppressed (Trueman, pers. com.). If the latter were the case, fluctuations in the abundance of *Trifolium* spp. may be expected and this has apparently been the case at Bushbury Hill since the survey.

The vigorous growth of the clovers noted at Bushbury Hill in 1987 is of some concern as legumes have the ability to fix large amounts of nitrogen (Marrs, in prep.) and thus significantly increase soil fertility. Marrs *et al* (1983) found that accumulation rates for *Trifolium pratense* in trial plots was 157kg N ha^{-1} $year^{-1}$ over a two year period. Legumes have been recommended for use in reclamation schemes on difficult substrates for this reason (Bradshaw & Chadwick, 1980). However increases in fertility brought about by nitrogen fixation by legumes could conceivably have the medium- to long-term effect of reducing species diversity in a created grassland sward.

Differences in the created vegetation were detectable between the experimental plots at Bushbury Hill and these seem to relate to the methods used during site preparation. A summary of the results of the survey of each plot are presented in Table 4.3 (p. 65).

Indicator Species Analysis of the quadrat data suggested that three distinct types of vegetation were present at Bushbury Hill. The analysis grouped together the majority of the quadrats from plots 1, 2 and 3 (group 0). All of the control plot quadrats, the plot 4 quadrats and a few quadrats recorded at the margins of the other three plots formed group 1 (Figure 4.2: p. 72). Figure 4.3 (p. 73) gives an indication of the relative positions of the quadrats and the ISA groups into which they were placed by the analysis.

The first ISA division suggests that a vegetation type has been established in most of plots 1, 2 and 3 which was distinct from that of the control plot and plot 4. Seven of the nine indicator species for group 0 are community constants within the Pennerley Meadows sward suggesting that this group includes stands which support a vegetation type which has affinities with that of the donor meadow.

The remaining two indicator species for group 0, *Rumex obtusifolius* and *Vicia sativa* are weeds in the experimental plots at Bushbury Hill and probably indicative of the disturbance resulting from preparation of these plots, in particular plots 1 and 2 which were rotovated. Both species were present at Bushbury Hill prior to the experiment in the areas of unmanaged grassland associated with the tree and shrub plantations adjacent to the meadow area.

The division of group 0 into groups 00 and 01 was difficult to interpret. However, the two groups formed were not associated with particular plots suggesting that the vegetation in plots 1, 2 and 3 did not vary according to the method of ground preparation used.

ISA group 1 tends to suggests that plot 4 bore more resemblance to the original amenity sward of Bushbury Hill, represented by the control plot, than to the created vegetation in plots 1, 2 and 3. The single indicator species for group 1, *Lolium perenne*, was a major component of the former amenity sward at Bushbury Hill and had survived in the control plot and plot 4 in which the original vegetation was retained.

The division of group 1, however, separated the stands recorded in plot 4 from those in the control plot, forming groups 10 and 11 respectively. The indicator species for group 10 includes a number which are constant species within the Pennerley Meadows sward. The division suggests that the vegetation in plot 4 bore some similarity to the donor meadow which, although it was not to the same degree as that of plots 1, 2 and 3, made it distinct from the original amenity sward.

Reciprocal Averaging Ordination produced results which supported the theory that three types of vegetation were present in the experimental plots. The stand ordination did not produce an even distribution of quadrats along the axes and when axis 1 is plotted against axis 2, three clusters are produced which correspond to the quadrats recorded in plots 1, 2 and 3 (ISA group 0), the quadrats recorded in plots 4 (ISA group 10) and the stands recorded in the control plot (ISA group 11) (Figure 4.4: p. 74).

Although the ISA results suggest that plots 1, 2 and 3 support a similar type of vegetation, despite the different approaches to site preparation used, some subtle differences can be detected between the mean % cover values of the constant species (Table 4.4: p. 68 and Figure 4.5: p. 75). Plots 1 and 2, for example, have a lower cover of *Festuca rubra* than plot 3. This species may have preferred the less disturbed soils present in plot 3 in which the pre-treatment involved no soil cultivation. Alternatively, its greater abundance in plot 3 may reflect survival from the original vegetation, in which it was abundant (This could also account for the greater abundance of other species in plot 3 compared to 1 and 2 such as *Lolium perenne* (see Table 4.3: p. 65) and *Holcus lanatus*). On the whole, however, the three plots all supported similar frequencies and abundances of the constant species, and these were not too dissimilar to the donor meadow.

The most noticeable difference between plots 1, 2 and 3 and the donor meadow primarily related to the structure/texture of the sward. Pennerley Meadows supported a short, grass dominated but herb-rich sward, but the created grassland in plots 1, 2 and 3 was coarser and had the appearance of being dominated by a number of forb species, notably *Leucanthemum vulgare* and *Trifolium pratense*.

Plot 4, on the other hand, supported vegetation that was less coarse in appearance to plots 1, 2 and 3. This was largely due to a lower frequency and abundance of *Leucanthemum vulgare*, but also due to a more complete grass cover which included high frequencies of species surviving from the original amenity sward (eg. *Lolium perenne* and *Poa trivialis*). As in plots 1, 2 and 3 *Festuca rubra* was the most abundant species in the sward but it is likely that this species had also survived in the amenity sward rather than being introduced with the hay.

Table 4.4 (p. 68) and Figure 4.5 (p. 75) show that despite receiving a minimum of preparation prior to seeding, plot 4 contained a number of the species regarded as community constants at Pennerley Meadows and which were probably introduced as seed in the hay (eg. *Leucanthemum vulgare*, *Ranunculus bulbosus* and *Rhinanthus minor*).

Rhinanthus minor was definitely not present at Bushbury Hill prior to the experiment and was introduced to plot 4 with the hay. As an annual which does not form a permanent seed bank (Roberts, 1986), it has the ability to establish in closed grassland swards such as that in plot 4, as it is dependent on this strategy for its own survival.

Few of the species found at lower frequencies at Pennerley Meadows, and which were not already present in the amenity sward at Bushbury Hill, had become established in plot 4 by the time of the survey. However, the results from plot 4 suggest that if a suitable donor site can be found, hay strewing can be used to diversify some types of well established grasslands after a minimum of ground preparation.

The results of the soil analysis (Table 4.5: p. 69) indicated that there was little variation between the experimental plots in terms of the parameters measured. There may be a slight trend of increasing fertility moving across the experimental area from the control plot to plot four, especially in terms of available phosphorus. However, this does not seem to relate to site preparation and is more likely to reflect existing variability in the soils at the experimental site.

The vegetation in the control plot contrasted strongly with that in the other plots. The overall diversity was low, and although it too was characterised by *Festuca rubra*, the abundance of *Holcus lanatus*, *Lolium perenne Dactylis glomerata* and *Trifolium pratense* in the plot reflects the composition of the amenity grassland sward present on the site prior to the experiment. Although some of these species were also characteristic of the Pennerley Meadows sward, ISA indicated that the similarity with the donor sward was generally low.

A limited number of other species found at Pennerley Meadows were present within the control plot sward, including *Achillea millefolium*, *Bellis perennis*, *Cerastium fontanum*, *Cynosurus cristatus* and *Plantago lanceolata*. However, these are common grassland species which are found in a wide range of situations and most were probably present at Bushbury Hill prior to the experiment. Their presence may reflect the relatively infertile soil at Bushbury Hill (Table 4.2: p. 64) and the length of time for which the site has been managed as permanent grassland (c. 20 years).

Although there may have been a slight increase in diversity of the control plot due to colonisation by species from the other experimental plots[1], the generally limited diversity in this plot emphasises the fact that in many instances grasslands cannot be quickly converted into diverse meadows by simply changing their management. This approach may be appropriate in certain circumstances (Sutherland and Gibson, 1988), particularly on sites which have supported grassland for many years[2], although in most cases some form of assisted species introduction is generally necessary.

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1. *Rhinanthus minor* was present in the control plot but not recorded during the quadrat survey

2. One area of grassland within the grounds of a school in Wolverhampton, having been closely mown for at least fifteen consecutive years by the Borough Council Parks Department, still supported a diverse flora with 28 meadow species flowering in the first year after mowing was relaxed.

4.4 Discussion

It is clear that by importing hay from Pennerley Meadows a new and interesting type of vegetation has been established at Bushbury Hill, which compares well with the vegetation of the donor meadow, both visually and in terms of the relative proportions of species present.

The results suggest that some form of site preparation, other than simply cutting the existing sward, favoured a more successful introduction of species from the donor site. However, there is also some evidence to suggest that excessive cultivation not only encourages undesirable weeds, but eliminates some species in the original sward which may be desirable. *Festuca rubra*, for example was more abundant in the plots which were not rotovated.

It is difficult to determine which of the approaches to site preparation used at Bushbury Hill was the most successful, particularly as no form of replication was introduced. However, as plots 1, 2 and 3 supported a similar vegetation type, it appears that disturbance of the soil through rotovation or ploughing, as used in plots 1 and 2, may not be necessary on some sites. Plot 3, in which the existing sward was simply killed prior to seeding, supported a created grassland sward in which a more complete grass cover had become established and which was as diverse as that in both plots 1 and 2. Although *Lolium perenne* was more abundant in plot 3 than in plots 1 and 2, largely due to survival from the original amenity sward, it was not the dominant species. The maintenance of an appropriate hay cutting regime will further help to restrict the vigour and abundance of this species.

It is apparent that importing freshly harvested hay may have advantages over dried hay as used at Peasley Wood meadow. The high abundance of *Holcus lanatus* at the Peasley Wood meadow in its first year suggests that the seed of this species may be retained within dry hay longer than that of the other species. The created meadow at Bushbury Hill had a noticeably higher abundance of some herbs, especially *Leucanthemum vulgare*, than that at Peasley Wood, probably indicating a reduction in the loss of their seed by eliminating the drying stage of the hay making process at the donor meadow. It seems feasible, therefore, that the total amount of seed retained within fresh hay, as opposed to dry hay, is higher and its use may allow a more uniformly successful transfer of species. It is, of course, dangerous to draw firm conclusions from comparisons of the experiments described in this and the previous chapter as there were significant physical differences between the two experimental areas which may well have had an effect on the establishment success.

The successful introduction of *Rhinanthus minor* into plot 4 is of interest. Grime *et al* (1988) indicate that *R. minor* is a summer-annual herb, found in a wide range of grassland habitats on soils of low to moderate fertility and, although capable of limited autotrophic growth, appears to be an obligate hemi-parasite. There is evidence to suggest that in cultivation *R. minor* does not need haustorial contact with a host to complete its life cycle (Hambler, 1958), but in nature the species is always encountered in the parasitic state and dependent on a rapid attachment to a host species from which it receives carbohydrates, water and mineral nutrients (Hodgson, 1973). It is estimated that *R. minor* must attach to a suitable host within 10 days of germination in order to survive (Gibson, 1986).

R. minor has a wide range of potential host species, particularly amongst members of the Gramineae and Leguminosae (Hodgson, 1973) and Gibson (1986) suggests that, although it is not specific in its host attachments, it demonstrates selectivity which may relate to the environmental conditions prevalent. Gibson (1986) suggests that the selectivity displayed by *R. minor* depresses the performance of some components of the community limiting their productivity. Studies of other hemi-parasitic species have also demonstrated similar effects (de Hullu, 1985; Snogerup, 1982).

Gibson also demonstrated how the host selectivity of *R. minor* may suppress some species to the benefit of others. This may well influence the structuring of natural communities.

Gibson (1981 & 1986) suggests that there is an apparent association between low species diversity and the presence of *Rhinanthus minor*. However, other workers consider that the species is generally associated with species-rich communities (Tansley, 1939; Sinker *et al*, 1985; Grime *et al*, 1988) and Gibson himself found that the physical removal of *R. minor* at one sand dune site resulted in the dominance of *Koeleria macrantha*, a preferred host for the parasite at this site, and a consequential reduction in the overall species diversity of the plot.

It appears that at Gibson's site the removal of *R. minor* allowed *K. macrantha* to flourish, to the detriment of other species in the community, and it seems feasible that where the favoured hosts are dominant members of the community, the presence of *R. minor* can decrease their vigour and increase overall sward diversity.

This may well be particularly beneficial in newly created grasslands which are often characterised by the dominance of one or two grass species (eg. *Holcus lanatus* - see Chapter 3), as by suppressing the vigour of otherwise dominant species, *R. minor* may enable a greater range of other non-host species to survive.

Some workers have experienced difficulties with the establishment of *R. minor* from seed mixtures. Wells *et al* (1981) found that the species failed to germinate in laboratory tests although they recorded good germination in the field. It seems that the hay strewing approach may be an effective way of introducing fresh, viable seed of this potentially valuable species to some established grass swards with subsequent high levels of germination success.

Overall the experiment at Bushbury Hill has satisfied the objectives behind its establishment. A moderately diverse grassland sward has been produced which resembles that of the semi-natural donor. The created meadow also provides a valued amenity landscape feature which provides colour and interest in an otherwise monotonous closely mown grassland. The meadow seems to be appreciated by the various users of the open space, who range from school children to elderly dog-walkers, without impinging too greatly on the existing grassland areas which thus retain their amenity and recreational value. In this respect, the choice of the site at Bushbury Hill seems to have been appropriate although it is of some interest that there is evidence that methane escaping from the buried tip is killing patches of the vegetation. This indicates that very often urban sites have hidden problems which may affect the success of habitat creation schemes. Site history is therefore perhaps as important a consideration in urban areas as it is on farmland which may have high residual levels of fertiliser.

TABLES

Table 4.1: Floristic table for Pennerley Meadows (1987) and Bushbury Hill Meadow Plots 1-4 Combined (1987).

a = frequency class, b = domin range.

	PENNERLEY		BUSHBURY	
Species	a	b	a	b
Agrostis capillaris	V	(2-8)	I	(4-5)
Anthoxanthum odoratum	V	(2-4)	III	(1-5)
Cynosurus cristatus	V	(1-5)	III	(2-5)
Dactylis glomerata	V	(1-5)	II	(2-6)
Festuca rubra	V	(5-9)	V	(3-8)
Holcus lanatus	V	(1-8)	V	(2-8)
Hypochoeris radicata	V	(1-4)	III	(1-3)
Leucanthemum vulgare	V	(1-6)	IV	(1-8)
Plantago lanceolata	V	(2-7)	V	(2-7)
Ranunculus bulbosus	V	(1-4)	V	(1-4)
Rhinanthus minor	V	(1-7)	V	(1-6)
Trifolium pratense	V	(1-6)	V	(1-6)
Briza media	IV	(1-4)	I	(1)
Hieracium pilosella	IV	(1-5)		
Rumex acetosa	IV	(1-5)	II	(1-3)
Trifolium repens	IV	(1-5)	IV	(1-6)
Trisetum flavescens	IV	(1-5)	IV	(2-7)

Table 4.1 continued:

Species	PENNERLEY a	PENNERLEY b	BUSHBURY a	BUSHBURY b
Cerastium fontanum	III	(1-3)	III	(1-3)
Lotus corniculatus	III	(1-5)		
Ranunculus acris	III	(1-3)	I	(2)
Conopodium majus	II	(1-3)		
Euphrasia officinalis agg.	II	(1-4)	I	(1)
Luzula campestris	II	(1-3)		
Veronica chamaedrys	II	(1-3)		
Achillea millefolium	I	(3)	I	(2-4)
Bellis perennis	I	(1-2)	II	(1-4)
Botrychium lunaria	I	(1-2)		
Campanula rotundifolia	I	(1)		
Centaurea nigra	I	(1-5)	I	(1-4)
Galium verum	I	(2)		
Heracleum sphondylium	I	(1-4)		
Lathyrus montanus	I	(1-3)		
L. pratensis	I	(1-3)		
Leontodon hispidus	I	(7)	I	(2-4)
Linum catharticum	I	(1-2)		
Lolium perenne	I	(1-4)	III	(1-8)
Platanthera chlorantha	I	(1)		
Potentilla erecta	I	(1-2)		
Primula veris	I	(1-6)		
Prunella vulgaris	I	(1-2)		
Pteridium aquilinum	I	(4)		
Rubus fruticosus agg.	I	(1)		
Taraxacum spp.	I	(1)	IV	(1-5)
Trifolium dubium	I	(1)	I	(1-3)
Vaccinium myrtillus	I	(2)		
Vicia cracca	I	(1-2)		
Viola lutea	I	(3)		
V. riviniana	I	(1-3)		

Table 4.1 continued:

Species	PENNERLEY a	PENNERLEY b	BUSHBURY a	BUSHBURY b
Agrostis stolonifera			I	(1-2)
Bromus hordeaceus			I	(2-3)
Cirsium arvense			I	(2-4)
C. vulgare			I	(4)
Equisetum arvense			I	(2-4)
Lamium album			I	(1-4)
Leontodon autumnalis			I	(1-3)
Medicago lupulina			I	(2)
Poa pratensis			III	(1-7)
P. trivialis			I	(1-2)
Ranunculus repens			I	(2)
Rumex crispus				
R. obtusifolius			I	(1-5)
Tussilago farfara			I	(2-4)
Urtica dioica			I	(1-3)
Vicia sativa			III	(1-5)

Summary	PENNERLEY	BUSHBURY
mean no. of species/quadrat	18.6	13.6
total no. of stands	111	94
total no. of species	48	41

Table 4.2: Analysis of Soils at Pennerley Meadows and Bushbury Hill (Mean Data).

	PENNERLEY	BUSHBURY
pH	5.7	7.5
NO_3 (ppm)	0.1	1.1
NH_4 (ppm)	5.1	3.7
P (ppm)	5.8	12.3
K (ppm)	67.6	123.6
% loss on ignition	19.4	9.7

Table 4.3: Floristic table for Pennerley Meadows (1987) and Bushbury Hill Meadow Plots (1987).

a = frequency class, b = domin range.

	PENNERLEY		BUSHBURY HILL									
			CONTROL		PLOT 1		PLOT 2		PLOT 3		PLOT 4	
Species	a	b	a	b	a	b	a	b	a	b	a	b
Agrostis capillaris	V	(2-8)					I	(4)	I	(4)	I	(4-5)
Anthoxanthum odoratum	V	(2-4)			IV	(1-4)	IV	(2-5)	IV	(1-4)		
Cynosurus cristatus	V	(1-5)	II	(1-4)	III	(2-4)	IV	(2-5)	V	(1-4)	I	(1-2)
Dactylis glomerata	V	(1-5)	IV	(1-6)	I	(2-3)	III	(2-5)	I	(2-6)	III	(2-6)
Festuca rubra	V	(5-9)	V	(5-8)	V	(3-8)	V	(3-7)	V	(4-8)	V	(7-8)
Holcus lanatus	V	(1-8)	V	(2-6)	V	(2-7)	V	(3-7)	V	(4-8)	IV	(2-7)
Hypochoeris radicata	V	(1-4)			I	(1-3)	IV	(1-3)	IV	(1-3)	I	(1)
Leucanthemum vulgare	V	(1-6)			V	(2-7)	V	(1-8)	V	(1-6)	I	(1)
Plantago lanceolata	V	(2-7)	I	(1-2)	V	(3-7)	V	(4-6)	V	(2-6)	IV	(1-5)
Ranunculus bulbosus	V	(1-4)			V	(1-4)	V	(2-4)	V	(1-3)	IV	(1-3)
Rhinanthus minor	V	(1-7)			V	(1-6)	V	(1-5)	V	(2-6)	V	(2-6)
Trifolium pratense	V	(1-6)	V	(2-6)	V	(2-6)	V	(2-6)	V	(2-6)	IV	(1-5)
Briza media	IV	(1-4)							I	(1)		
Hieracium pilosello	IV	(1-5)										
Rumex acetosa	IV	(1-5)			I	(1-2)	III	(1-3)	III	(1-3)		
Trifolium repens	IV	(1-5)			IV	(2-5)	IV	(2-4)	V	(1-5)	IV	(1-6)
Trisetum flavescens	IV	(1-5)			V	(2-6)	V	(2-6)	V	(3-7)	I	(4)

Table 4.3 continued:

Species	PENNERLEY		BUSHBURY HILL									
			CONTROL		PLOT 1		PLOT 2		PLOT 3		PLOT 4	
	a	b	a	b	a	b	a	b	a	b	a	b
Cerastium fontanum	III	(1-3)	II	(1-2)	III	(2-3)	IV	(1-3)	III	(1-3)	II	(1-3)
Lotus corniculatus	III	(1-5)										
Ranunculus acris	III	(1-3)					I	(2)				
Conopodium majus	II	(1-3)										
Euphrasia officinalis agg.	II	(1-4)					I	(1)				
Luzula campestris	II	(1-3)										
Veronica chamaedrys	II	(1-3)										
Achillea millefolium	I	(3)	II	(1-3)			I	(2-4)				
Bellis perennis	I	(1-2)	II	(1-3)	II	(2-4)	II	(1-2)	I	(1-2)	I	(1-2)
Botrychium lunaria	I	(1-2)										
Campanula rotundifolia	I	(1)										
Centaurea nigra	I	(1-5)			I	(1-2)	I	(1-4)	I	(4)		
Galium verum	I	(2)										
Heracleum sphondylium	I	(1-4)										
Lathyrus montanus	I	(1-3)										
L. pratensis	I	(1-3)										
Leontodon hispidus	I	(7)							I	(2-4)		
Linum catharticum	I	(1-2)										
Lolium perenne	I	(1-4)	V	(2-5)	II	(1-5)	I	(3-7)	III	(2-6)	V	(5-8)
Platanthera chlorantha	I	(1)										
Potentilla erecta	I	(1-2)										
Primula veris	I	(1-6)										
Prunella vulgaris	I	(1-2)										
Pteridium aquilinum	I	(4)										
Rubus fruticosus agg.	I	(1)										
Taraxacum spp.	I	(1)	I	(1)	IV	(1-4)	II	(1-3)	III	(1-4)	V	(2-5)
Trifolium dubium	I	(1)	II	(1-3)	II	(1-3)	I	(1)				
Vaccinium myrtillus	I	(2)										
Vicia cracca	I	(1-2)										
Viola lutea	I	(3)										
V. riviniana	I	(1-3)										

Table 4.3 continued:

Species	PENNERLEY		BUSHBURY HILL									
			CONTROL		PLOT 1		PLOT 2		PLOT 3		PLOT 4	
	a	b	a	b	a	b	a	b	a	b	a	b
Agrostis stolonifera					I	(2)			I	(1)		
Bromus hordeaceus					I	(2-3)						
Cirsium arvense							I	(2)			I	(4)
C. vulgare									I	(4)		
Equisetum arvense					I	(2-4)					I	(3)
Lamium album					I	(4)	I	(1-3)	I	(1)		
Leontodon autumnalis							I	(1)	I	(1)	II	(1-3)
Medicago lupulina									I	(2)		
Poa pratensis			II	(2-3)	III	(1-5)	I	(1-7)	III	(1-5)	V	(2-6)
P. trivialis			IV	(2-4)	I	(1-2)						
Ranunculus repens			II	(2-4)	I	(2)					I	(1)
Rumex crispus			I	(1)								
R. obtusifolius					I	(1-4)	III	(1-4)	I	(5)	I	(4)
Tussilago farfara							I	(2-4)				
Urtica dioica					I	(2-3)	I	(1)				
Vicia sativa			II	(2-3)	IV	(2-4)	V	(2-5)	II	(1-3)	II	(1-3)

Summary	PENNERLEY	BUSHBURY HILL				
		CONTROL	PLOT 1	PLOT 2	PLOT 3	PLOT 4
mean no. of species/quadrat	18.6	7.9	13.7	15.6	14.5	10.6
total no. of stands	111	12	21	25	25	23
total no. of species	48	17	30	32	30	24

Table 4.4: Frequency and Abundance of Pennerley Meadows Constant Species in the Experimental Plots at Bushbury Hill

a = frequency class, b = domin range, c = mean % cover

Species	PENNERLEY			CONTROL			PLOT 1			PLOT 2			PLOT 3			PLOT 4		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Agrostis capillaris	V	(2-8)	18.44							I	(4)	0.28	I	(4)	0.56	I	(4-5)	1.09
Anthoxanthum odoratum	V	(2-4)	3.47				IV	(1-4)	2.33	IV	(2-5)	4.24	IV	(1-4)	2.60			
Cynosurus cristatus	V	(1-5)	2.33	II	(1-4)	0.92	III	(2-4)	1.43	IV	(2-5)	3.16	V	(1-4)	3.20	I	(1-2)	0.17
Dactylis glomerata	V	(1-5)	4.72	IV	(1-6)	8.96	I	(2-3)	0.33	III	(2-5)	2.76	I	(2-6)	1.34	III	(2-6)	4.67
Festuca rubra	V	(5-9)	46.12	V	(5-8)	42.67	V	(3-8)	17.55	V	(3-7)	14.44	V	(4-8)	38.88	V	(7-8)	53.87
Holcus lanatus	V	(1-8)	12.60	V	(2-6)	11.46	V	(2-7)	16.59	V	(3-7)	25.76	V	(4-8)	35.12	IV	(2-7)	6.28
Hypochoeris radicata	V	(1-4)	2.15				I	(1-3)	0.33	IV	(1-3)	1.60	IV	(1-3)	1.32	I	(1)	0.04
Leucanthemum vulgare	V	(1-6)	9.86				V	(2-7)	10.24	V	(1-8)	18.00	V	(1-6)	11.04	I	(1)	0.09
Plantago lanceolata	V	(2-7)	12.96	I	(1-2)	0.25	V	(3-7)	12.95	V	(4-6)	14.96	V	(2-6)	10.28	IV	(1-5)	3.43
Ranunculus bulbosus	V	(1-4)	3.04				V	(1-4)	2.43	V	(2-4)	2.56	V	(1-3)	1.96	IV	(1-3)	1.09
Rhinanthus minor	V	(1-7)	11.93				V	(1-6)	5.88	V	(1-5)	3.84	V	(2-6)	13.02	V	(2-6)	10.74
Trifolium pratense	V	(1-6)	6.55	V	(2-6)	9.50	V	(2-6)	12.38	V	(2-6)	12.02	V	(2-6)	12.22	IV	(1-5)	5.96
Briza media	IV	(1-4)	1.40										I	(1)	0.04			
Hieracium pilosella	IV	(1-5)	2.17															
Rumex acetosa	IV	(1-5)	1.82				I	(1-2)	0.57	III	(1-3)	1.00	III	(1-3)	0.68			
Trifolium repens	IV	(1-5)	2.23				IV	(2-5)	3.19	IV	(2-4)	3.16	V	(1-5)	4.56	IV	(1-6)	5.85
Trisetum flavescens	IV	(1-5)	3.12				V	(2-6)	7.95	V	(2-6)	10.90	V	(3-7)	19.46	I	(4)	0.17

Table 4.5: Analysis of Soils in the Experimental Plots at Bushbury Hill.

	PENNERLEY	BUSHBURY HILL PLOTS C	1	2	3	4
pH	5.7	7.2	7.6	7.2	7.5	7.9
NO_3 (ppm)	0.1	0.3	1.1	2.0	1.3	0.8
NH_4 (ppm)	5.1	5.2	3.9	2.5	3.8	3.0
P (ppm)	5.8	6.0	9.5	12.0	12.0	22.0
K (ppm)	67.6	115.5	125.0	124.5	110.5	142.5
% loss on ignition	19.4	11.4	9.7	8.7	9.7	9.0
texture	silt loam	sandy loam	sandy loam	sandy loam	sandy clay loam	sandy clay loam

FIGURES

Figure 4.1: Plan of the Experimental Area at Bushbury Hill Showing the Relative Positions of the Plots (not to scale).

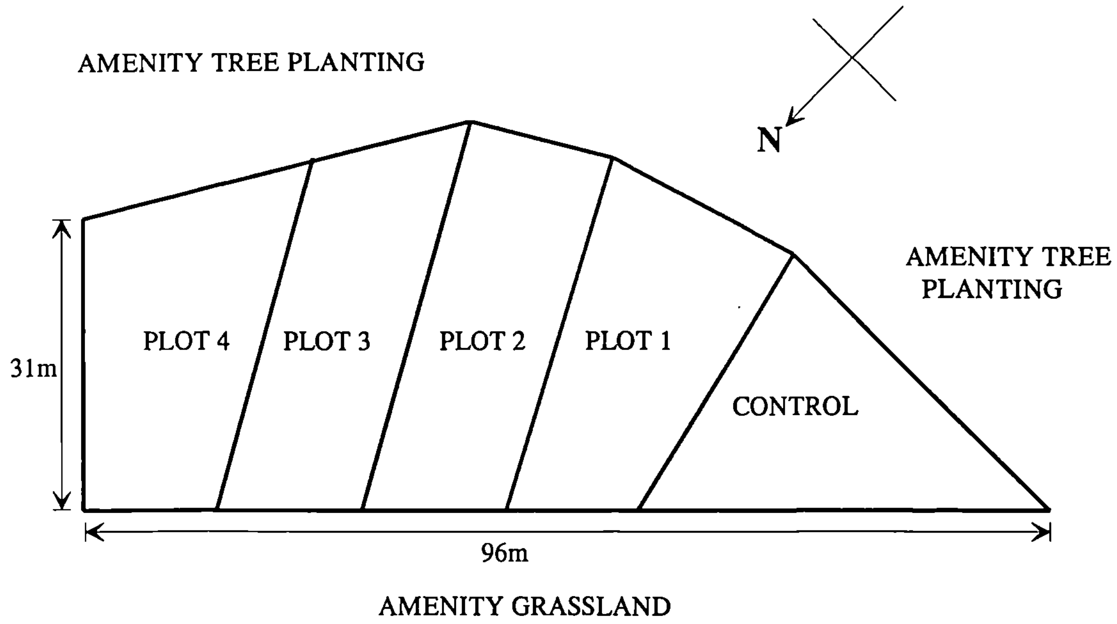


Figure 4.2: Dendrogram Showing Divisions in Indicator Species Analysis for Bushbury Hill (1987).

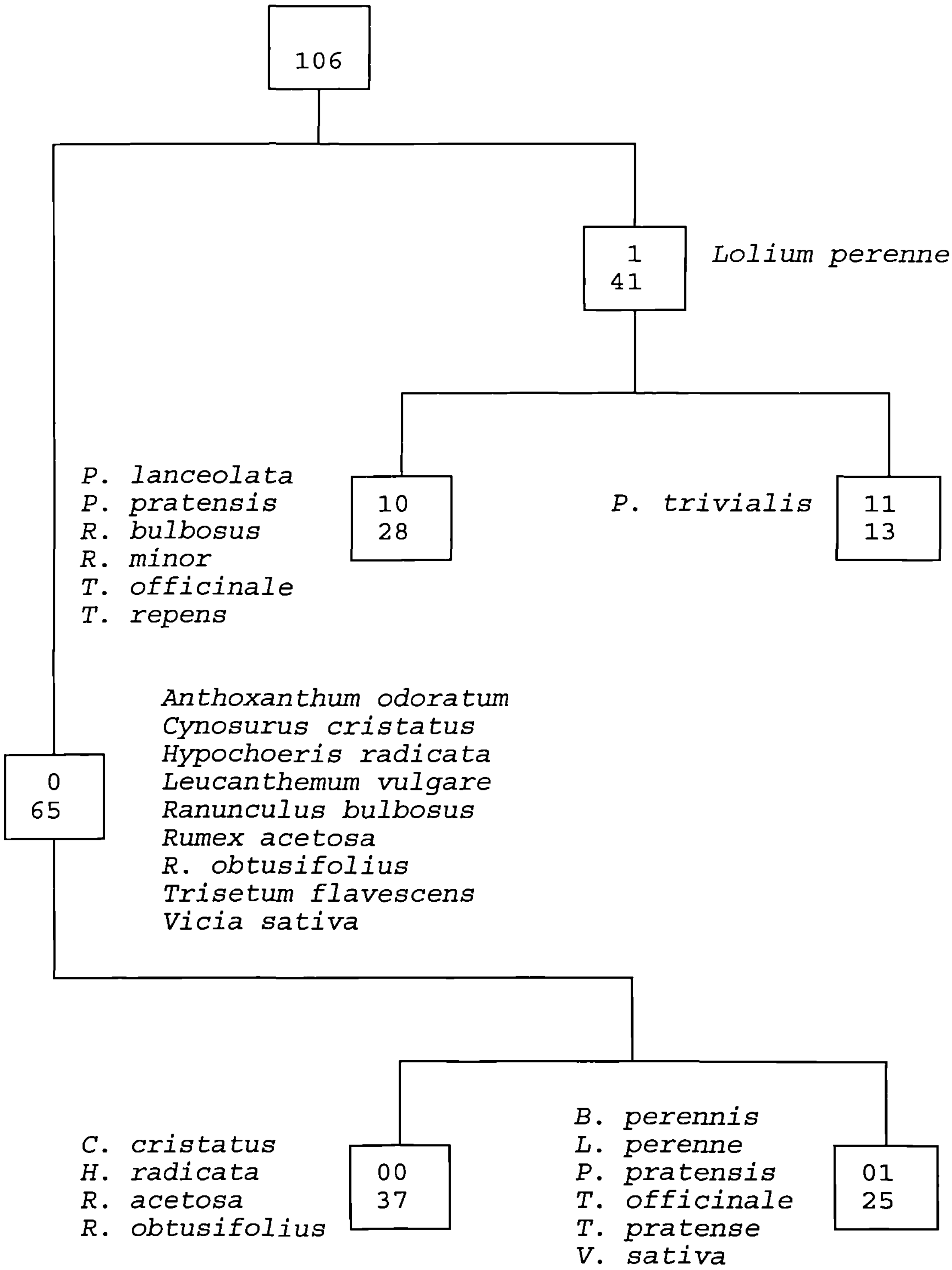


Figure 4.3: Plan of the Experimental Area at Bushbury Hill Showing the Distribution of Survey Quadrats Between ISA Groups (not to scale).

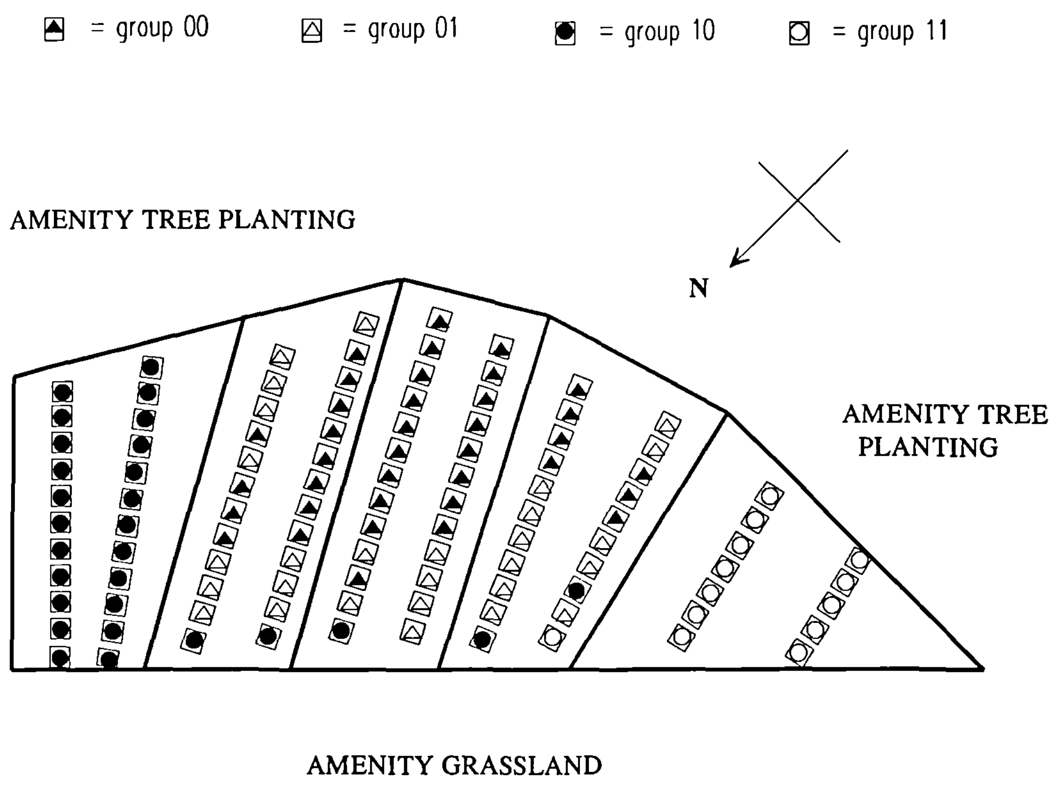


Figure 4.4: Graph Showing the Distribution of Quadrats on Axis 1 and Axis 2 of the Reciprocal Averaging Stand Ordination of the Bushbury Hill Data with ISA Groups Superimposed.

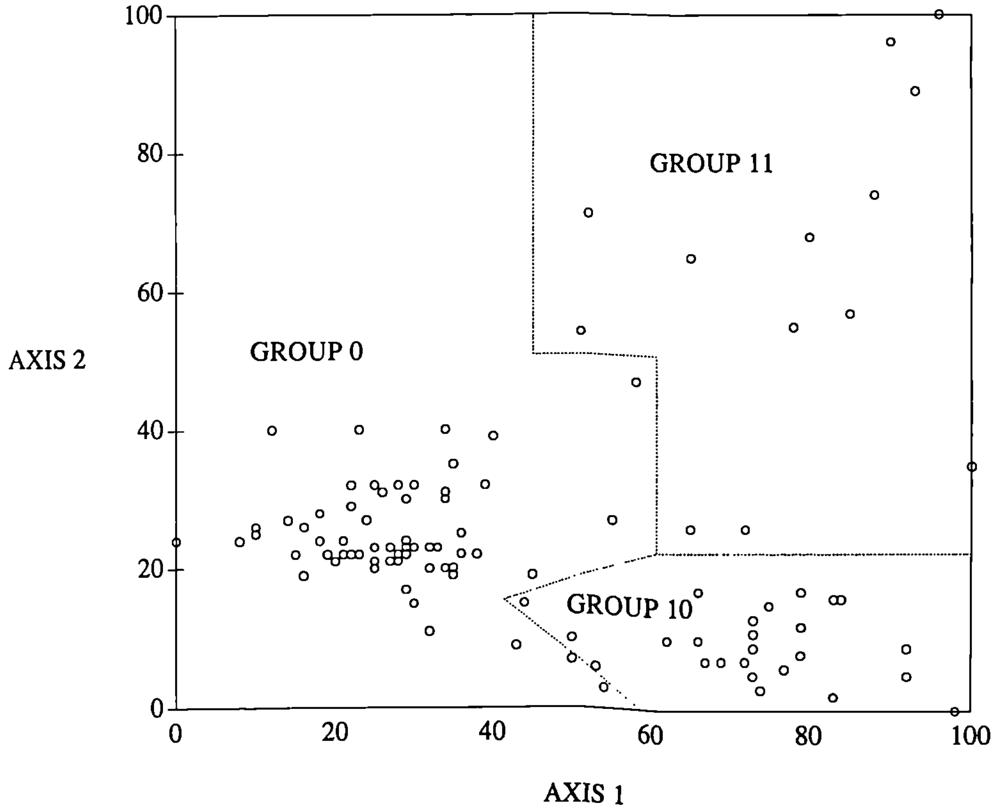
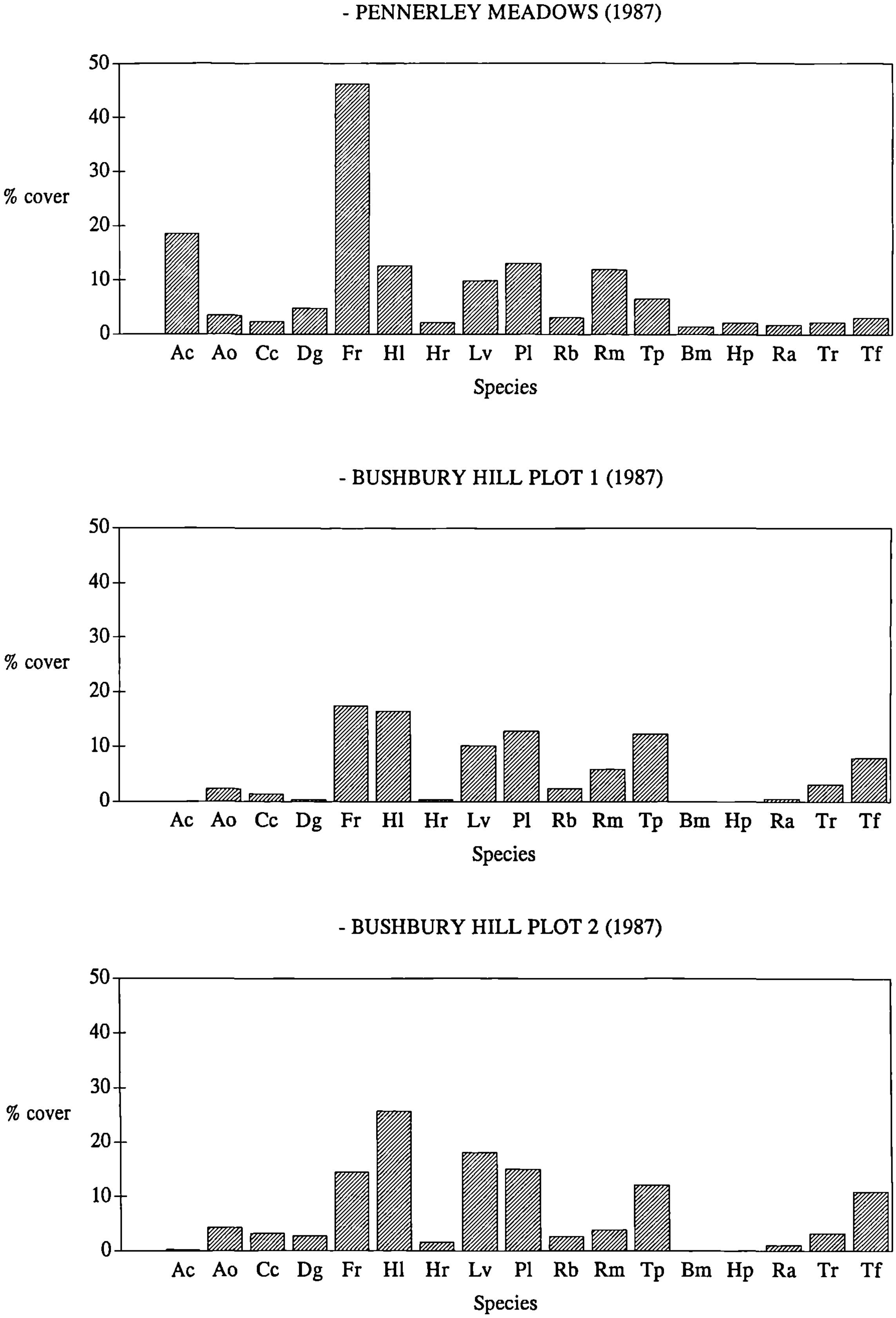


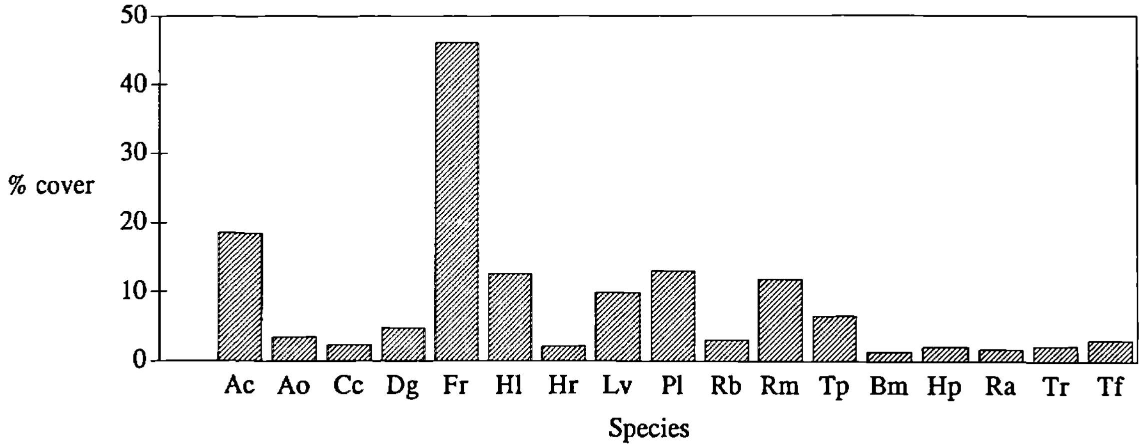
Figure 4.5: Histograms Showing the Mean % Cover of Constant Species at Pennerley Meadows and Bushbury Hill.



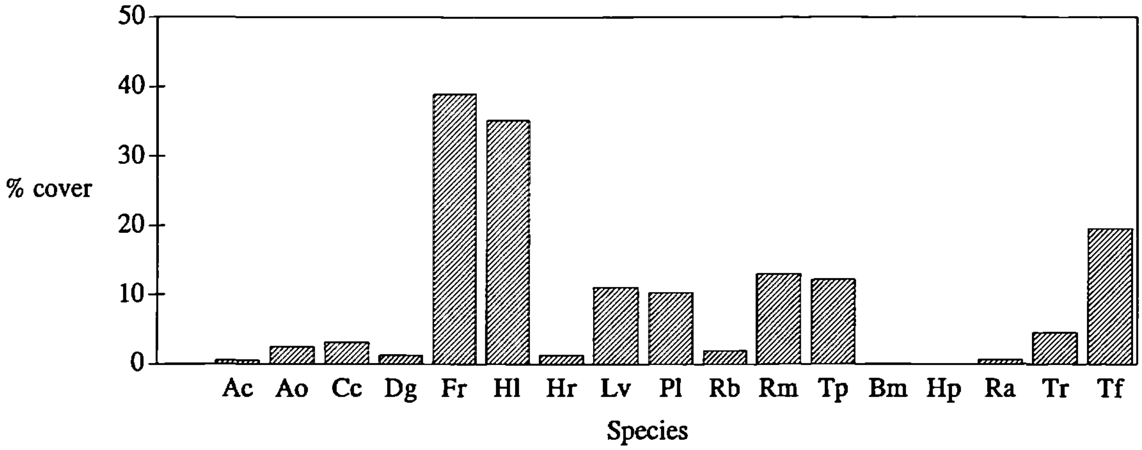
NOTE: Abreviations are used for species names; species are given in the same order as shown in Table 4.4.

Figure 4.5 Continued:

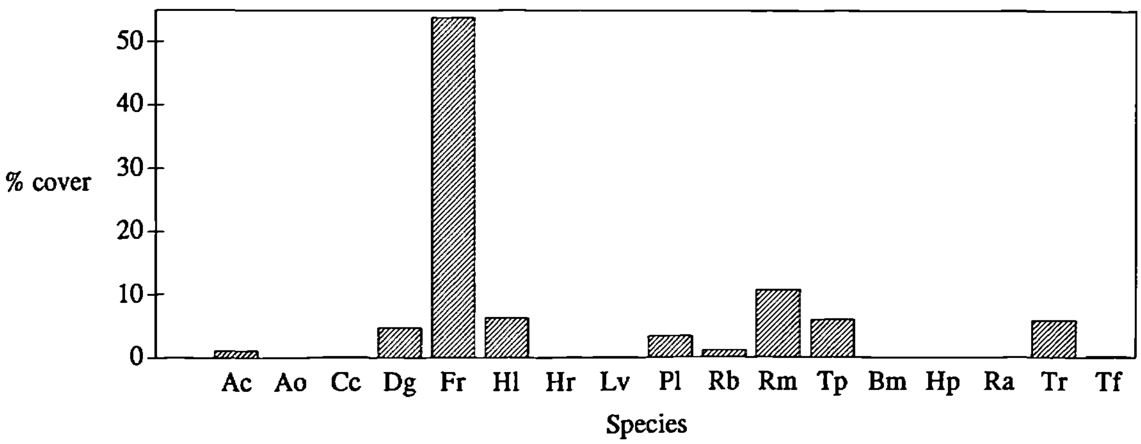
- PENNERLEY MEADOWS (1987)



- BUSHBURY HILL PLOT 3 (1987)



- BUSHBURY HILL PLOT 4 (1987)



NOTE: Abreviations are used for species names; species are given in the same order as shown in Table 4.4.

CHAPTER 5

An Assessment of the Value of Cropping with Potatoes as a Pre-treatment to Species-Rich Grassland Creation

5.0 An Assessment of the Value of Cropping with Potatoes as a Pre-treatment to Species-Rich Grassland Creation

5.1 Introduction

The important relationship between soil fertility and plant species diversity in grasslands has been discussed in Chapter 1 of this report. Although habitats with a high conservation value have developed on some abandoned agricultural land in the past (eg. Sheail, 1979; Marrs & Proctor, 1979; Wells *et al*, 1976), a high soil fertility usually counteracts attempts to create species-rich grasslands. Marrs & Gough (1989) suggest that if seeds of many species are sown onto fertile substrates during habitat creation schemes, the high fertility would favour those introduced species which are high yielding and competitive over slower growing species and the ultimate success in terms of sward diversity would be restricted. The fertility of an experimental substrate is consequently an important first consideration for grassland creation.

Bakker (1987) suggests that "restoration management" (i.e. management aimed at increasing the ecological value of an area often by increasing species diversity) may aim to reduce the residual effects of earlier fertiliser applications. However, it appears that little research has been undertaken to investigate the deliberate impoverishment of soils during habitat creation (Marrs and Gough, 1989).

Marrs (in press) suggests that deliberate management to deplete the nutrient supply by maximising crop offtake is an obvious approach to reducing soil fertility. Hay-making without fertiliser application will, in theory, have the effect of gradually impoverishing the grassland soil and has been adopted during some "restoration management" projects (Bakker, 1987). However, the extended timescales required to see significant decreases in soil fertility using this approach (Johnston & Penny, 1972; Wells, 1980) may be prohibitive during habitat creation. Furthermore, it has been suggested that a typical hay crop may only remove as much nitrogen as is contained in the rainfall of some urban areas (Ash *et al*, 1992; Marrs & Gough, 1989) and this approach may therefore have limitations on fertile sites in towns and cities.

Other, more drastic, approaches to soil depletion used or suggested include turf stripping/top-soil removal (Diemont *et al*, 1982) which Marrs & Gough (1989) consider to possibly be one of the best alternatives for already cultivated agricultural soils, deep ploughing/profile reversal (Ash *et al*, 1992), sub-soil importation (Emery, 1986) and the mixing of soil and infertile materials (Ash *et al*, 1992).

Most arable crops have a high nutrient demand and continual cropping of soils without fertiliser inputs gradually exhausts the pool of available nutrients. Arable cropping on experimental sites has been used in Holland before attempts to establish diverse plant communities (Londo, 1977). Marrs (1985) also investigated the value of growing crops on abandoned arable land in Suffolk for reducing the high levels of soil nutrients before the restoration of *Calluna vulgaris* dominated heathland. This approach has now been adopted during the restoration of grasslands and heathlands in the Breckland Environmentally Sensitive Area (Marrs & Gough, 1989; MAFF, 1988).

In this chapter a simple experiment is discussed in which a crop of potatoes was grown prior to meadow creation. Chapter 6 describes a replicated experiment in which several crops were grown and compared.

The success of attempts to reduce soil fertility can be measured in a number of ways. Changes in soil chemistry determined by chemical analysis may be used. However Petgel (1987) suggests that the soil nutrient content determined by extraction methods may not represent nutrient availability to plants. Soils comprise of a number of potential nutrient pools including the minerals, soil organic matter, exchangeable/extractable nutrients and the soil solution (Marrs, 1985; Marrs, in press). Although each of these nutrient pools can be estimated chemically (Allen *et al,* 1974), such estimates will only provide limited information on soil fertility in terms of availability of nutrients to plants as this also depends on the relative rates of transfer between the nutrient pools (Marrs, 1985; Marrs, in press). Nutrient availability is also dependent on various plant characteristics, and the specific conditions under which a plant grows.

Some techniques used to impoverish soils, such as hay-making once a year without fertiliser additions, may result in a very low nutrient removal from the soil nutrient store (Bakker, 1987) and, as a consequence, not clearly affect the nutrient status of the soil. However, some workers have noted a rapid decrease in above-ground production and an increase in the number of species characteristic of nutrient impoverished situations when such impoverishment techniques are employed (Pegtel, 1987). Thus techniques to reduce soil fertility (or the availability of plant nutrients in the soil) may clearly have beneficial results without producing measurable changes in soil chemistry.

Phytometric or bioassay procedures have been used to measure soil fertility (eg. Al-Farraj *et al,* 1984; Marrs, 1985; Petgel, 1987; Wheeler *et al,* 1992). Using this approach soil fertility is compared by measuring the yield or performance of a test plant grown under controlled conditions in a known volume or mass of soil. Marrs (in press) points out some disadvantages of the phytometric approach, suggesting that different species respond differently to nutrient availability and also that disturbance during soil sample collection results in changes to soil structure and thus nutrient availability. The phytometric approach gives no absolute index of fertility and results are therefore only valid for comparison between treatments within one experiment.

In the experiment described in this chapter, the relative species diversity and abundance of introduced species was used as an indicator of changes in soil fertility brought about by cropping whilst in the experiment described in Chapter 6 a combination of species composition and above ground biomass was used.

Land was made available for the grassland creation experiment at Merridale Infants School, Wolverhampton (SO 901981). The school is situated within two miles of the centre of Wolverhampton and was built in 1976 on the site of a smallholding. The school grounds, which are unusually large for an urban infants school, are bordered on three sides by housing and on the fourth by the open ground of Merridale Cemetery which dates back to at least the 1850's.

A number of habitat creation projects had already been undertaken at the school prior to the experiment described in this chapter and included a woodland and a bog garden (Trueman & Lawley, in prep.; Jones, 1990). The school grounds are enclosed and also 'patrolled' by the schools well-informed caretaker who resides on the premises which are thus protected to some degree from vandalism.

The area set aside for meadow creation was approximately 70m long by 10m wide and prior to the school being built had been part of the smallholding. It is understood that the area had formerly been divided into paddocks, some being used for donkeys/ponies, others being left empty and neglected. No accurate record of the management used on the site remains.

The experimental area supported a close mown grassland sward maintained as part of the surrounding playing fields. It was bounded on one side by the perimeter fence of the school grounds with private gardens beyond. A row of recently planted ash and elm trees grew along the other long boundary, with amenity grassland at either end. Although intensively mown by the Local Authority, a limited range of plant species were present including *Bellis perennis* and *Veronica filiformis* in addition to a number of grasses. The soil had a mean pH of 5.65

5.2 Methods

5.2.1 Site Preparation and Seeding

Site preparation commenced on 13 April 1987 when the original playing-field sward was killed using a Glyphosate herbicide. On 28 April 1987, after the herbicide had taken effect, the whole experimental area was ploughed and divided into four plots measuring approximately 5m x 35m. Two days later two of the plots were planted very densely with a second early variety of potato (Scottish Estemma) using a tractor mounted potato planter. The two planted and two unplanted plots were diagonally opposite to compensate for any variations in the edaphic conditions in the long thin experimental area (Figure 5.1; p. 98). None of the plots were weeded and the potatoes were allowed to grow without fertiliser or irrigation.

On 18 July 1987 the crop of potatoes was lifted using a tractor drawn potato lifter and the school children were recruited to pick and bag the crop. During the harvest as much above- and below-ground plant material was removed as possible.

The whole experimental area was then harrowed with a spring-tine harrow to produce a level seed bed and on 28 July 1987 was sprayed with a contact herbicide containing paraquat to kill any surviving weeds.

The hay from field 7214 at Pennerley Meadows (Chapter 2) was cut on 3 August 1987. The following day, in an attempt to retain as much seed as possible from the donor meadow, the hay crop was big-baled and four bales, the product of approximately 0.24ha, were transported to Merridale School and spread over the experimental area to form a loose 10cm thick layer. The hay was allowed to dry for several weeks, during which it was turned by hand, and was then removed from the site.

The created grassland was cut during early August 1988 and the hay crop removed by hand after several days. After several weeks the experimental area was returned to the regular gang-mowing regime used to maintain the surrounding playing fields and consequently received another 2 or 3 cuts before the end of the season. It is intended that this management approach be formalised in the form of a management plan for the school grounds which is currently in preparation.

5.2.2 Survey Methods

The meadow vegetation was surveyed in mid July in both 1988 and 1989. On each occasion four transect lines were run the length, and down the centre, of the four experimental plots. Records were made of the percentage cover of plant species present within a 1m x 1m quadrat positioned at 2m intervals along the transect lines. A total of 68 quadrats were recorded for the experimental area in both years (ie. 17 from each plot).

Ten random soil samples were taken from each of the experimental plots. Samples were taken using an auger with a core diameter of 7cm to a depth of approximately 12cm. The random samples collected from each plot were combined and thoroughly mixed. Parameters measured were nitrate nitrogen, ammonium nitrogen, available phosphorus and available potassium. Standard analytical methods were used for the analyses (Ministry of Agriculture, Fisheries and Food, 1986).

5.3 Results

The potato plants grew well in the light friable soil at the experimental site and, despite the early harvest time, good sized potatoes were lifted with the total crop exceeding 800lbs. The high density at which the potatoes were planted did not appear to inhibit their growth. It was apparent, however, that the dense above ground foliage of the potato plants did suppress weed growth as the potato plots remained weed free whilst a high density of weeds established in the unplanted plots.

Despite the high crop yield, chemical analysis of the soils at the experimental site suggested that there was little difference between the plots in terms of nitrogen, phosphorus and potassium after crop harvest (Table 5.1: p. 89). The analyses indicated that the soil in all plots was deficient in terms of nitrogen but that moderate to high levels of phosphorus and potassium were available.

Following the introduction of the hay, a dense grassland sward developed rapidly at the experimental site. By the spring of 1988 all four plots supported an almost closed, grass dominated sward in which seedlings of many of the forbs present in the donor meadow were present. The results of the vegetation surveys undertaken in 1988 and 1989 are summarised in Table 5.2 (p. 90) & Table 5.3 (p. 93) using the same approach as adopted previously in this report.

Overall (Table 5.2: p. 90) the number of species introduced to the new meadow at Merridale had increased in comparison with the earlier experiments at Peasley Wood and Bushbury Hill (Chapters 3 & 4). A total of 63 species were present in 1988, the first year after meadow establishment, and 51 in 1989. Such a decline in total numbers of species frequently occurs during the early years of a created meadow as 'weed' species are eliminated by competition. By 1989 only 18 such 'weed' species were recorded in the Merridale School meadow, compared with 33 in 1988.

The decline in weed species also accounts for the reduction in the mean numbers of species recorded per quadrat between 1988 and 1989. However, the mean number of species per quadrat recorded in 1989 (16.6) was closer to that recorded at Pennerley Meadows (18.6) than the figures obtained for either the experimental plots (plots 1 to 4) at Bushbury Hill in 1987 (13.6) or the Peasley Wood site in 1987 (8.9). Although this figure is still influenced by the presence of the weed species, it is apparent that by 1989 only sixteen of the species recorded at Pennerley Meadows in 1987 were absent from the created meadow. Fourteen of these absent species were recorded at low frequencies (frequency class I) in the donor sward and, with the exception *Leontodon hispidus*, they also all had maximum domin values of 4 or lower. Furthermore, four of these species, *Potentilla erecta*, *Pteridium aquilinum*, *Rubus fruticosus agg.* and *Vaccinium myrtillus*, may be considered to be weeds within the donor meadow (Chapter 2).

The establishment success therefore seems to have been higher at the Merridale School site than in the previous experiments. A number of attractive donor meadow species absent from the created meadows at both Peasley Wood and Bushbury Hill plots were recorded during the created meadow at the school by 1989, albeit at low frequencies and levels of abundance, including *Primula veris*, *Lotus corniculatus*, *Hieracium pilosella*, *Luzula campestris*, *Lathyrus montanus*, *L. pratensis*, *Linum catharticum* and *Prunella vulgaris*.

All of the constant species in the Pennerley Meadows sward (Table 2.4: p. 22) were represented within the created meadow at Merridale School by its second season (1989). Several of these species had either appeared for the first time in 1989 (*Briza media*) or were recorded at higher frequency levels than in the previous year (*Dactylis glomerata*, *Trifolium pratense*, *Trifolium repens*). However, there were also decreases in the frequency of some of the constant species in the second season compared to the first (eg. *Cynosurus cristatus* & *Ranunculus bulbosus*), although these were generally small.

There were noticeable differences between the plots in terms of the visual appearance of the created vegetation in 1988 and these persisted into 1989. The uncropped plots supported what appeared to be a coarser grass sward with a higher abundance of *Holcus lanatus* than the cropped plots. The observed differences between the treatments in terms of the abundance of this species are not reflected in the summary presented in Table 5.3 (p. 93). However, if the mean percentage cover values for *H. lanatus* are considered (Table 5.4: p. 96) it is clear that, although much more abundant in both years and in all plots than it was at Pennerley Meadows, *H. lanatus* was more abundant in the uncropped plots than in the cropped plots (Figure 5.2: p. 99).

In Chapter 3 it was suggested that the high quantities of *H. lanatus* in created swards may be a reflection of its ability to colonise open habitats. It was noted by Miles (1974a & 1974b) that the establishment of this species from seed was much better on infertile soils if complete NPK fertiliser was applied although laboratory and field trials have shown that it can tolerate low levels of N, P and K (Watt, 1978). Although there are many potential differences between the cropped and uncropped plots at Merridale School it is feasible that the variation in the amounts of *H. lanatus* noted is a response to different levels of soil fertility resulting from the cropping treatment. Thus cropping could have beneficial effects on the establishment of other meadow species by reducing the ability of *H. lanatus* to suppress them during the early stages of meadow establishment.

Although the cropped and uncropped plots were generally similar in terms of the frequency and abundance of the other constant and lower frequency (frequency classes III to I) species (Table 5.3: p. 93), there were some interesting differences. The mean % cover of *Agrostis capillaris* for example, although significantly greater in all the experimental plots at Merridale School than had been achieved in experiments described previously (Chapters 3 & 4), was greater in the cropped plots than the uncropped plots in both 1988 and 1989 (Table 5.4: p. 96 & Figure 5.3: p. 100).

This was also the case for *Festuca rubra* which, by 1989, was approaching the levels of abundance recorded at the donor meadow (Figure 5.4: p. 101). Indeed, a histogram showing the mean % cover values for the constant species (Figure 5.5: p. 102) indicates that by 1989 the created meadow sward in the potato plots was very similar to that of the donor meadow. As suggested above, the sward in the cropped plots was noticeably less coarse in comparison to that present in the uncropped plots, and these results suggest that the cropping treatment did seem to have a beneficial effect, even after only one season.

5.4 Discussion

It was concluded in previous chapters that strewing fresh, green hay from Pennerley Meadows is superior to strewing dried hay in terms of species establishment during grassland creation. However, some donor meadow species, particularly early and late season flowering species, still failed to become established or were only present at reduced frequencies in the created meadows when fresh hay was used.

It also became clear that the movement of loose hay from donor sites to experimental sites involves an inefficient use of time and a considerable degree of man-handling of a bulky seed carrying medium.

In an attempt to both retain as much seed as possible within the hay crop from the donor meadow and increase the efficiency of the hay strewing technique, more efficient methods of collection and transportation have been investigated during the present study.

During the experiment at Merridale School, big-baled hay from Pennerley Meadows was used. Big-balers, unlike conventional balers, can be readily used to bale freshly cut grass. The apparent increased success in terms of donor species introductions recorded at the Merridale School meadow is an indication that big-baling is a more efficient method of translocating seed from donor to experimental site. Although it was not economically feasible to collect hay from Pennerley Meadows on more than one occasion in the season, which would have reduced the chance of missing early or late flowering species, the use of big-bales appeared to be an effective means of maximising seed collection at any one time. In addition to collecting a large proportion of the seed either ripening or ripe but still retained by the plants with a minimum of threshing, the big-bale method also collects litter which may contain previously shed seed.

The use of big-baled hay has not been compared with other methods of collecting hay in any quantitative way during the present study and the apparent benefits noted could be a result of many other factors such as site suitability, the nature of the experimental soils and the precise timing of the hay cut during the different experiments. However, the use of big-baled hay as a seed carrying medium had several other advantages over the movement of loose hay:

a) The collection of loose hay is usually a time consuming approach and involves a high input of manual labour to load and unload the hay. The use of big-baled hay was significantly quicker and more labour efficient. One man with a tractor and the appropriate equipment was able to bale and load the hay from one acre of Pennerley Meadows in approximately 1 hour. Furthermore, only two or three people are required to 'unroll' and spread the bales at the experimental site.

b) The heat generated by anaerobic fermentation of fresh hay when stored, even for very short periods of time, can be damaging to viable seed. Using big-bales, the time between baling and 'unrolling' can be minimised and the problem of seed loss due to over-heating also minimised.

c) The use of big-bales is financially competitive with other methods being used to create diverse grassland swards. At the time of the experiment at Merridale School, commercial seed mixtures collected from diverse meadows such as North Meadow SSSI, Wiltshire, cost, on average, £40-£45 per kg plus VAT. At a recommended seeding rate of approximately 16.19kg/acre (40kg/ha) the total cost of the seed required for a 1 acre experimental area would be approximately £647.60 plus VAT and postage. For special seed mixes the cost per kg can be much higher (Chapter 7).

In contrast, the approximate cost of sufficient fresh hay from Pennerley Meadows to seed a 1 acre experimental plot in Wolverhampton was £275 (cost of hay from a 1 acre = £120, cutting, baling and loading = £75, transport [½day @ £20 per hour] = £80). Furthermore, this figure is based on the assumption that the ratio of size of donor meadow to the size of experimental site is 1:1 which is approximately correct although much smaller amounts of hay have been used successfully in Wolverhampton.

The costs of site preparation and actual seeding (or spreading of hay) have not been included although there is evidence to suggest that cheaper seed beds may be sufficient when using fresh hay as a seed medium (cf. Bushbury Hill Plot 3).

d) The use of big bales is also a method that can be easily arranged by local authorities during the implementation of such schemes, provided suitable donor meadows can be located, as the machinery required is widely available.

The cropping treatment used at Merridale School appeared to have beneficial results in terms of the species composition of the created sward despite the fact that no meaningful differences in soil chemistry were detected. Furthermore, the differences noted in the created sward between cropped and uncropped plots were apparent after only a single cropping season. It is clear, however, that these results may be a reflection of the relatively infertile soil present at the site prior to the experiment and that on more fertile sites cropping for several seasons may be required for noticeable changes to be detected. Some fertile sites may never be suitable for the creation of species-rich grasslands.

Marrs (in press) suggests that the mechanisms which cause a decline in species-richness are not necessarily reversed simply by reducing fertility. He explains how Parr (1986) developed a catastrophe model which may explain the limited bi-directionality of the fertility/diversity relationship.

Parr (1986) agrees that a theoretical transition between moderately fertile and fertile sites results in a decline in species-richness. However, rather than a simple linear decline, he envisaged a high diversity trajectory and a low diversity trajectory with a jump from the high to the low trajectory at a threshold level of fertility. He suggested that the jump between the trajectories is not simply bi-directional and that if fertility is subsequently reduced, species richness may increase but only on the low diversity trajectory. This may have important implications for grassland creation on fertile sites as it would suggest that attempts to create grasslands on soils with levels of fertility higher than the Parr's threshold may be immediately restricted to the low diversity trajectory.

Overall the experiment at Merridale School has demonstrated that cropping with potatoes can be a beneficial pre-treatment prior to grassland creation on some sites. Records of the use of cropping before habitat creation are scarce in the literature. Where it is mentioned, it is usually with reference to the use of cereal crops; the author has found no reference to the use of potatoes in published work although they were used between 1876 and 1901 in the Exhaustion Land Experiment at Rothamsted (Marrs, in press; Johnston & Poulton, 1977). In the next chapter an experiment is described in which potatoes are compared with two other, possibly more widely used, crops; maize and barley.

TABLES

Table 5.1: Analysis of Soils at Merridale School Meadow (1988)

Parameter	Cropped	Uncropped
NO_3 (ppm)	3.6	3.0
NH_4 (ppm)	1.6	1.5
P (ppm)	59.5	55.5
K (ppm)	201.5	205.5

Table 5.2: Floristic Table for Pennerley Meadows (1987) and Merridale School Meadow (1988 & 1989).

a = frequency class, b = domin range.

	Pennerley		Merridale School			
	1987		1988		1989	
Species	a	b	a	b	a	b
Agrostis capillaris	V	(2-8)	III	(1-4)	IV	(1-5)
Anthoxanthum odoratum	V	(2-4)	V	(1-5)	V	(2-6)
Cynosurus cristatus	V	(1-5)	V	(1-3)	IV	(1-4)
Dactylis glomerata	V	(1-5)	I	(1)	III	(1-7)
Festuca rubra	V	(5-9)	V	(2-7)	V	(2-9)
Holcus lanatus	V	(1-8)	V	(4-10)	V	(2-10)
Hypochoeris radicata	V	(1-4)	V	(1-5)	V	(1-4)
Leucanthemum vulgare	V	(1-6)	V	(1-5)	V	(2-5)
Plantago lanceolata	V	(2-7)	V	(1-7)	V	(1-7)
Ranunculus bulbosus	V	(1-4)	V	(1-3)	IV	(1-3)
Rhinanthus minor	V	(1-7)	V	(1-4)	V	(1-3)
Trifolium pratense	V	(1-6)	III	(1-4)	V	(1-8)
Briza media	IV	(1-4)	-	-	I	(1)
Hieracium pilosella	IV	(1-5)	I	(1-2)	I	(1)
Rumex acetosa	IV	(1-5)	III	(1-3)	III	(1-3)
Trifolium repens	IV	(1-5)	II	(1-5)	IV	(1-5)
Trisetum flavescens	IV	(1-5)	III	(1-3)	III	(1-4)

Table 5.2 continued:

Species	Pennerley 1987 a	Pennerley 1987 b	Merridale School 1988 a	Merridale School 1988 b	Merridale School 1989 a	Merridale School 1989 b
Cerastium fontanum	III	(1-3)	V	(1-4)	IV	(1-3)
Lotus corniculatus	III	(1-5)	I	(4)	I	(3)
Ranunculus acris	III	(1-3)	IV	(1-3)	III	(1-3)
Conopodium majus	II	(1-3)	-	-	-	-
Euphrasia officinalis agg.	II	(1-4)	I	(1-2)	I	(1-2)
Luzula campestris	II	(1-3)	I	(1-2)	I	(1-2)
Veronica chamaedrys	II	(1-3)	-	-	-	-
Achillea millefolium	I	(3)	-	-	-	-
Bellis perennis	I	(1-2)	II	(1-2)	II	(1-2)
Botrychium lunaria	I	(1-2)	-	-	-	-
Campanula rotundifolia	I	(1)	-	-	-	-
Centaurea nigra	I	(1-5)	II	(1-3)	II	(1-4)
Galium verum	I	(2)	-	-	-	-
Heracleum sphondylium	I	(1-4)	I	(1)	I	(1)
Lathyrus montanus	I	(1-3)	I	(1)	-	-
L. pratensis	I	(1-3)	-	-	I	(1)
Leontodon hispidus	I	(7)	-	-	-	-
Linum catharticum	I	(1-2)	-	-	I	(1)
Lolium perenne	I	(1-4)	I	(1)	I	(5)
Platanthera chlorantha	I	(1)	-	-	-	-
Potentilla erecta	I	(1-2)	-	-	-	-
Primula veris	I	(1-6)	I	(1)	I	(2)
Prunella vulgaris	I	(1-2)	I	(1)	I	(1-2)
Pteridium aquilinum	I	(4)	-	-	-	-
Rubus fruticosus agg.	I	(1)	-	-	-	-
Taraxacum spp.	I	(1)	I	(1)	I	(1)
Trifolium dubium	I	(1)	I	(4)	II	(1-9)
Vaccinium myrtillus	I	(2)	-	-	-	-
Vicia cracca	I	(1-2)	-	-	-	-
Viola lutea	I	(3)	-	-	-	-
V. riviniana	I	(1-3)	-	-	-	-

Table 5.2 continued:

Species	Pennerley 1987 a	Pennerley 1987 b	Merridale School 1988 a	Merridale School 1988 b	Merridale School 1989 a	Merridale School 1989 b
Acer psuedoplatanus	-	-	I	(1)	-	-
Agrostis gigantea	-	-	I	(2-4)	I	(2-5)
Articum minus	-	-	I	(1-4)	I	(4)
Bromus sterilis	-	-	I	(1)	I	(2)
Capsella bursa-pastoris	-	-	I	(1-2)	-	-
Cirsium arvense	-	-	-	-	I	(1)
C. vulgare	-	-	II	(1-4)	I	(1-4)
Crataegus monogyna	-	-	I	(1)	II	(1-2)
Epilobium ciliatum	-	-	IV	(1-2)	I	(1-2)
Fraxinus excelsior	-	-	II	(1-2)	I	(1)
Galium aparine	-	-	I	(1-2)	I	(1-3)
Lamium album	-	-	I	(1-2)	-	-
L. purpureum	-	-	I	(1-2)	-	-
Lapsana communis	-	-	I	(1)	-	-
Leontodon autumnalis	-	-	-	-	I	(1)
Papaver rhoeas	-	-	I	(1)	-	-
P. sp.	-	-	I	(1)	-	-
Plantago major	-	-	I	(1)	-	-
Poa pratensis	-	-	I	(1-2)	-	-
P. trivialis	-	-	II	(1-2)	-	-
Ranunculus repens	-	-	II	(1-5)	I	(1-2)
R. obtusifolius	-	-	II	(1-4)	I	(1-5)
Sagina procumbens	-	-	I	(1)	-	-
Sisymbrium officinale	-	-	I	(1-4)	-	-
Solanum dulcamara	-	-	I	(1)	-	-
S. tuberosum	-	-	II	(1)	-	-
Sonchus asper	-	-	I	(1-2)	-	-
S. oleraceus	-	-	I	(1)	-	-
Spergularia sp.	-	-	-	-	I	(1)
Stachys sylvatica	-	-	I	(1-4)	I	(1-2)
Stellaria graminea	-	-	-	-	I	(1)
Tanacetum parthenium	-	-	I	(1)	-	-
Urtica dioica	-	-	I	(1)	I	(1-2)
Veronica arvensis	-	-	I	(1)	-	-
Vicia hirsuta	-	-	I	(1-4)	III	(1-10)
V. sativa	-	-	I	(1-3)	-	-
V. tetrasperma	-	-	I	(1)	I	(1-5)

Summary	Pennerley 1987	Merridale School 1988	Merridale School 1989
mean no. sp/quadrat	18.6	18.1	16.6
total no. of stands	111	68	68
total no. of species	48	63	50

Table 5.3: Floristic Table for Pennerley Meadows (1987) and Merridale School Meadow (1988 & 1989) Showing Mean Results for Cropped and Uncropped Plots.

a = frequency class, b = domin range.

	PENNERLEY		MERRIDALE SCHOOL							
			POTATO '88		NO CROP '88		POTATO '89		NO CROP '89	
Species	a	b	a	b	a	b	a	b	a	b
Agrostis capillaris	V	(2-8)	IV	(1-4)	III	(1-4)	IV	(2-5)	III	(1-4)
Anthoxanthum odoratum	V	(2-4)	V	(1-5)	V	(1-5)	V	(2-6)	V	(2-6)
Cynosurus cristatus	V	(1-5)	V	(1-3)	V	(1-3)	IV	(2-4)	V	(1-3)
Dactylis glomerata	V	(1-5)	I	(1)	I	(1)	III	(2-7)	III	(1-4)
Festuca rubra	V	(5-9)	V	(3-7)	V	(2-6)	V	(2-9)	V	(2-8)
Holcus lanatus	V	(1-8)	V	(4-10)	V	(4-10)	V	(2-9)	V	(2-10)
Hypochoeris radicata	V	(1-4)	V	(2-5)	V	(1-5)	V	(1-4)	V	(1-4)
Leucanthemum vulgare	V	(1-6)	V	(1-5)	V	(1-5)	V	(2-5)	V	(3-5)
Plantago lanceolata	V	(2-7)	V	(2-6)	V	(1-7)	V	(1-7)	V	(1-7)
Ranunculus bulbosus	V	(1-4)	V	(1-3)	V	(1-3)	IV	(1-3)	IV	(1-3)
Rhinanthus minor	V	(1-7)	V	(1-4)	V	(1-4)	V	(1-3)	IV	(1-3)
Trifolium pratense	V	(1-6)	II	(1-4)	III	(1-4)	V	(1-5)	IV	(1-8)
Briza media	IV	(1-4)	-	-	-	-	I	(1)	I	(1)
Hieracium pilosella	IV	(1-5)	I	(2)	I	(1)	I	(1)	I	(1)
Rumex acetosa	IV	(1-5)	III	(1-3)	IV	(1-2)	IV	(1-3)	II	(1-3)
Trifolium repens	IV	(1-5)	II	(2)	III	(1-5)	IV	(1-5)	IV	(1-8)
Trisetum flavescens	IV	(1-5)	IV	(1-3)	III	(1-3)	III	(1-3)	III	(1-4)
Cerastium fontanum	III	(1-3)	V	(1-4)	V	(1-4)	IV	(1-3)	IV	(1-3)
Lotus corniculatus	III	(1-5)	-	-	I	(4)	-	-	I	(3)
Ranunculus acris	III	(1-3)	IV	(1-3)	IV	(1-3)	IV	(1-3)	III	(1-2)
Conopodium majus	II	(1-3)	-	-	-	-	-	-	-	-
Euphrasia officinalis agg.	II	(1-4)	I	(1-2)	I	(1-2)	I	(1-2)	I	(1)
Luzula campestris	II	(1-3)	I	(1)	I	(1)	II	(1-2)	I	(1)
Veronica chamaedrys	II	(1-3)	-	-	-	-	-	-	-	-

Table 5.3 continued:

	PENNERLEY		MERRIDALE SCHOOL							
			POTATO '88		NO CROP '88		POTATO '89		NO CROP '89	
Species	a	b	a	b	a	b	a	b	a	b
Achillea millefolium	I	(3)	-	-	-	-	-	-	-	-
Bellis perennis	I	(1-2)	III	(1-2)	II	(1)	III	(1-2)	II	(1-2)
Botrychium lunaria	I	(1-2)	-	-	-	-	-	-	-	-
Campanula rotundifolia	I	(1)	-	-	-	-	-	-	-	-
Centaurea nigra	I	(1-5)	II	(1-3)	I	(1-2)	II	(2-3)	II	(1-4)
Galium verum	I	(2)	-	-	-	-	-	-	-	-
Heracleum sphondylium	I	(1-4)	-	-	I	(1)	I	(1)	I	(1)
Lathyrus montanus	I	(1-3)	I	(1)	-	-	-	-	-	-
L. pratensis	I	(1-3)	-	-	-	-	I	(1)	-	-
Leontodon hispidus	I	(7)	-	-	-	-	-	-	-	-
Linum catharticum	I	(1-2)	-	-	-	-	I	(1)	-	-
Lolium perenne	I	(1-4)	I	(1)	-	-	I	(5)	-	-
Platanthera chlorantha	I	(1)	-	-	-	-	-	-	-	-
Potentilla erecta	I	(1-2)	-	-	-	-	-	-	-	-
Primula veris	I	(1-6)	I	(1)	-	-	I	(2)	-	-
Prunella vulgaris	I	(1-2)	I	(1)	I	(1)	I	(1-2)	I	(1)
Pteridium aquilinum	I	(4)	-	-	-	-	-	-	-	-
Rubus fruticosus agg.	I	(1)	-	-	-	-	-	-	-	-
Taraxacum spp.	I	(1)	-	-	I	(1)	-	-	I	(1)
Trifolium dubium	I	(1)	-	-	I	(4)	II	(2-4)	III	(1-9)
Vaccinium myrtillus	I	(2)	-	-	-	-	-	-	-	-
Vicia cracca	I	(1-2)	-	-	-	-	-	-	-	-
Viola lutea	I	(3)	-	-	-	-	-	-	-	-
V. riviniana	I	(1-3)	-	-	-	-	-	-	-	-
Acer psuedoplatanus	-	-	I	(1)	II	(1)	-	-	-	-
Agrostis gigantea	-	-	I	(2-4)	II	(2-4)	II	(2-5)	-	-
Articum minus	-	-	I	(1-4)	-	-	I	(4)	-	-
Bromus sterilis	-	-	-	-	I	(1)	-	-	I	(2)
Capsella bursa-pastoris	-	-	I	(1-2)	II	(1-2)	-	-	-	-
Cirsium arvense	-	-	-	-	-	-	-	-	I	(1)
C. vulgare	-	-	II	(1-4)	I	(1)	I	(1-2)	I	(1-4)
Crataegus monogyna	-	-	I	(1)	I	(1)	II	(1-2)	II	(1-2)

Table 5.3 continued:

Species	PENNERLEY		MERRIDALE SCHOOL							
			POTATO '88		NO CROP '88		POTATO '89		NO CROP '89	
	a	b	a	b	a	b	a	b	a	b
Epilobium ciliatum	-	-	IV	(1-2)	IV	(1-2)	I	(1)	II	(1-2)
Fraxinus excelsior	-	-	II	(1)	III	(1-2)	I	(1)	I	(1)
Galium aparine	-	-	I	(1-2)	I	(1-2)	I	(2-3)	II	(1-3)
Lamium album	-	-	I	(1)	I	(2)	-	-	-	-
L. purpureum	-	-	I	(1-2)	I	(1)	-	-	-	-
Lapsana communis	-	-	-	-	I	(1)	-	-	-	-
Leontodon autumnalis	-	-	-	-	-	-	I	(1)	-	-
Papaver rhoeas	-	-	I	(1)	-	-	-	-	-	-
P. sp.	-	-	-	-	I	(1)	-	-	-	-
Plantago major	-	-	I	(1)	-	-	-	-	-	-
Poa pratensis	-	-	I	(1)	I	(1-2)	-	-	-	-
P. trivialis	-	-	II	(2)	II	(1-2)	-	-	-	-
Ranunculus repens	-	-	III	(2-4)	II	(1-5)	II	(1-2)	I	(1-2)
R. obtusifolius	-	-	II	(1)	I	(1-4)	II	(1-5)	I	(1-4)
Sagina procumbens	-	-	I	(1)	I	(1)	-	-	-	-
Sisymbrium officinale	-	-	II	(1-2)	I	(1-4)	-	-	-	-
Solanum dulcamara	-	-	-	-	I	(1)	-	-	-	-
S. tuberosum	-	-	III	(1)	I	(1)	-	-	-	-
Sonchus asper	-	-	II	(1-2)	I	(1-2)	-	-	-	-
S. oleraceus	-	-	I	(1)	II	(1)	-	-	-	-
Spergularia sp.	-	-	-	-	-	-	I	(1)	I	(1)
Stachys sylvatica	-	-	I	(1-4)	-	-	I	(1-2)	I	(1)
Stellaria graminea	-	-	-	-	-	-	I	(1)	I	(1)
Tanacetum parthenium	-	-	I	(1)	-	-	-	-	-	-
Urtica dioica	-	-	I	(1)	I	(1)	I	(1)	I	(1-2)
Veronica arvensis	-	-	I	(1)	-	-	-	-	-	-
Vicia hirsuta	-	-	I	(2)	I	(1-4)	III	(1-4)	II	(1-10)
V. sativa	-	-	I	(1-3)	I	(1-2)	-	-	-	-
V. tetrasperma	-	-	-	-	I	(1)	I	(1-2)	I	(2-5)

Summary	PENNERLEY	MERRIDALE SCHOOL			
		POTATO '88	NO CROP '88	POTATO '89	NO CROP '89
mean no. sp/quadrat	18.6	18.5	17.7	17.4	15.7
total no. of stands	111	34	34	34	34
total no. of species	48	54	54	47	44

Table 5.4: Frequency and Abundance of the Pennerley Meadows Constant Species in the Experimental Plots at Merridale School.

a = frequency class, b = domin range, c = mean % cover

	PENNERLEY			MERRIDALE SCHOOL											
				POTATO '88			NO CROP '88			POTATO '89			NO CROP '89		
Species	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Agrostis capillaris	V	(2-8)	18.44	IV	(1-4)	2.70	III	(1-4)	0.92	IV	(2-5)	3.53	III	(1-4)	1.91
Anthoxanthum odoratum	V	(2-4)	3.47	V	(1-5)	6.97	V	(1-5)	4.26	V	(2-6)	13.15	V	(2-6)	12.38
Cynosurus cristatus	V	(1-5)	2.33	V	(1-3)	1.85	V	(1-3)	2.44	IV	(2-4)	1.85	V	(1-3)	2.03
Dactylis glomerata	V	(1-5)	4.72	I	(1)	0.03	I	(1)	0.09	III	(2-7)	5.00	III	(1-4)	1.06
Festuca rubra	V	(5-9)	46.12	V	(3-7)	15.06	V	(2-6)	11.32	V	(2-9)	42.79	V	(2-8)	16.41
Holcus lanatus	V	(1-8)	12.60	V	(4-10)	36.06	V	(4-10)	47.88	V	(2-9)	21.50	V	(2-10)	32.06
Hypochoeris radicata	V	(1-4)	2.15	V	(2-5)	7.03	V	(1-5)	4.65	V	(1-4)	3.35	V	(1-4)	2.76
Leucanthemum vulgare	V	(1-6)	9.86	V	(1-5)	10.50	V	(1-5)	9.56	V	(2-5)	8.59	V	(3-5)	7.29
Plantago lanceolata	V	(2-7)	12.96	V	(2-6)	18.65	V	(1-7)	20.15	V	(1-7)	16.71	V	(1-7)	20.21
Ranunculus bulbosus	V	(1-4)	3.04	V	(1-3)	2.15	V	(1-3)	1.94	IV	(1-3)	1.79	IV	(1-3)	1.61
Rhinanthus minor	V	(1-7)	11.93	V	(1-4)	3.00	V	(1-4)	2.80	V	(1-3)	2.38	IV	(1-3)	2.21
Trifolium pratense	V	(1-6)	6.55	II	(1-4)	1.18	III	(1-4)	1.92	V	(1-5)	5.09	IV	(1-8)	7.56
Briza media	IV	(1-4)	1.40	-	-	-	-	-	-	I	(1)	0.03	I	(1)	0.03
Hieracium pilosella	IV	(1-5)	2.17	I	(2)	0.09	I	(1)	0.12	I	(1)	0.03	I	(1)	0.03
Rumex acetosa	IV	(1-5)	1.82	III	(1-3)	0.88	IV	(1-2)	1.21	IV	(1-3)	1.09	II	(1-3)	0.62
Trifolium repens	IV	(1-5)	2.23	II	(2)	0.53	III	(1-5)	1.33	IV	(1-5)	4.85	IV	(1-8)	6.26
Trisetum flavescens	IV	(1-5)	3.12	IV	(1-3)	1.21	III	(1-3)	1.03	III	(1-3)	1.09	III	(1-4)	1.15
Number of species	17			16			16			17			17		

FIGURES

Figure 5.1: Plan of the Experimental Area at Merridale School, Wolverhampton, Showing the Relative Positions of the Plots (not to scale).

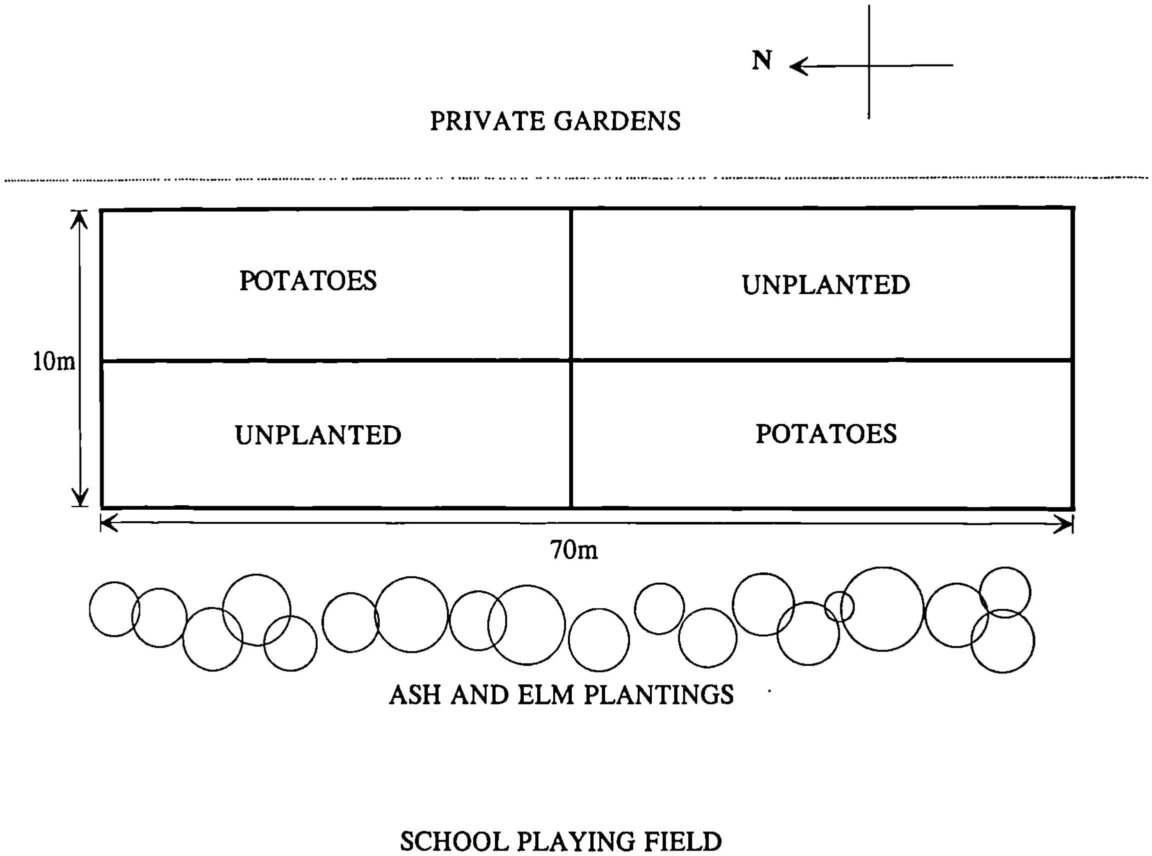


Figure 5.2: Histogram Showing the Mean % Cover of *Holcus lanatus* at Pennerley Meadows and in the Experimental Plots at Merridale School.

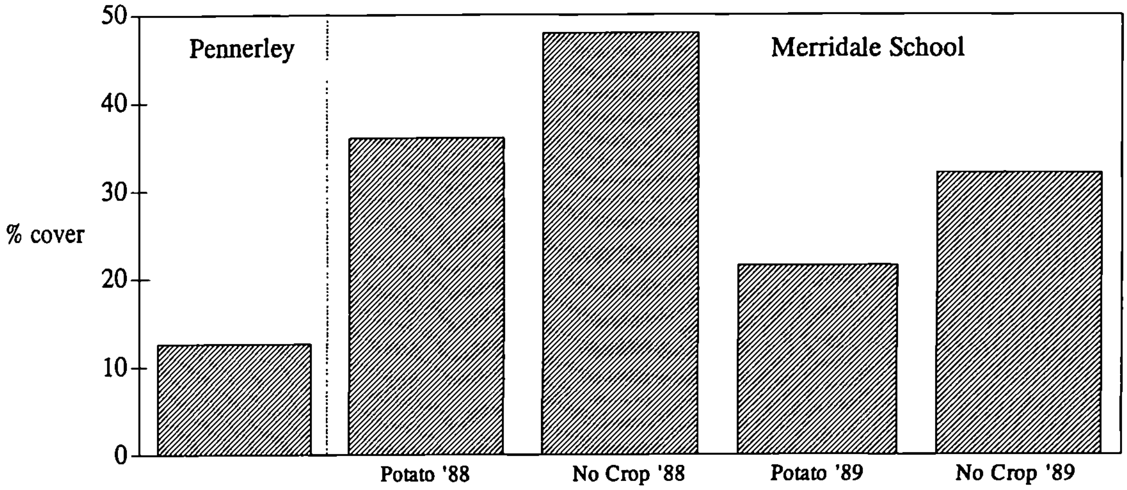


Figure 5.3: Histogram Showing the Mean % Cover of *Agrostis capillaris* at Pennerley Meadows and in the Experimental Plots at Merridale School.

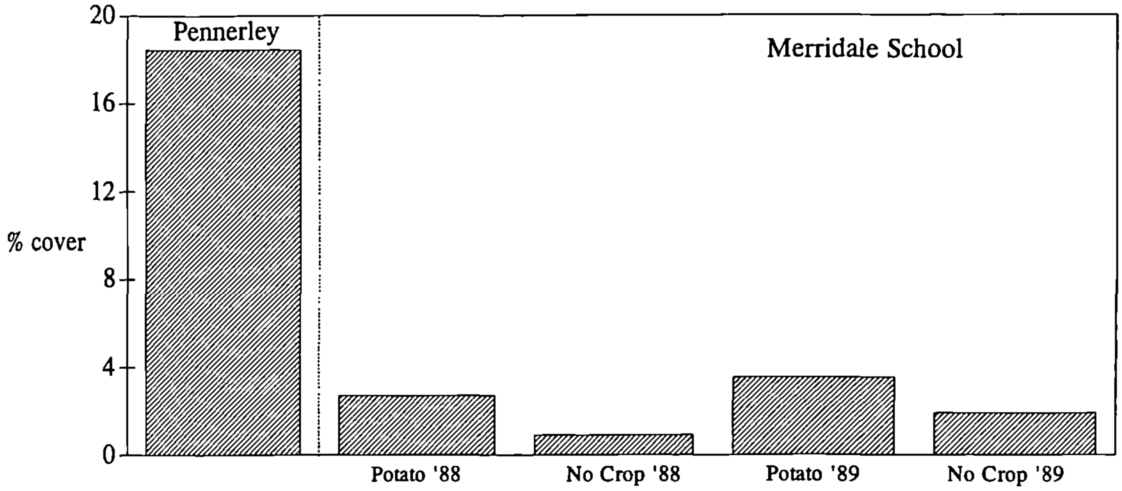


Figure 5.4: Histogram Showing the Mean % Cover of *Festuca rubra* at Pennerley Meadows and in the Experimental Plots at Merridale School.

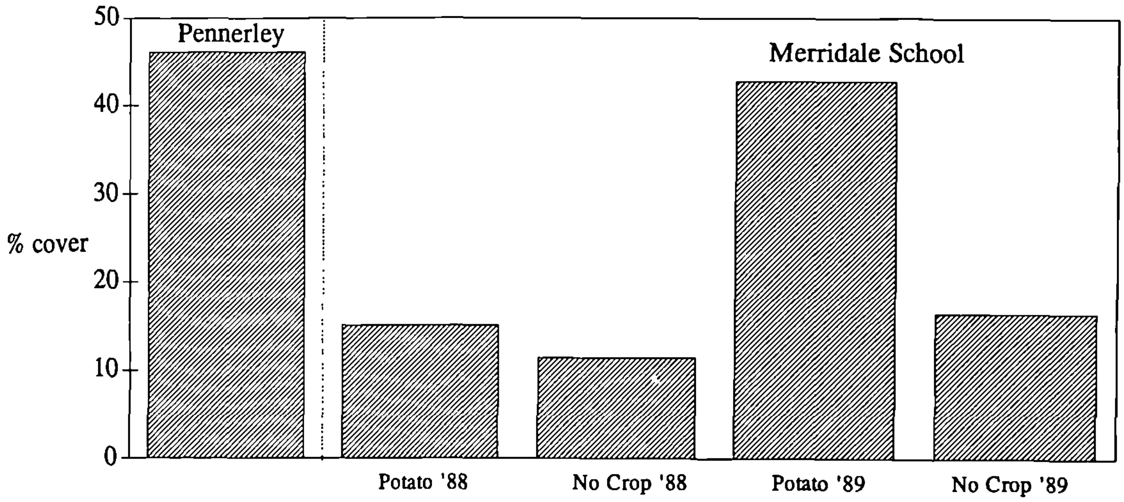
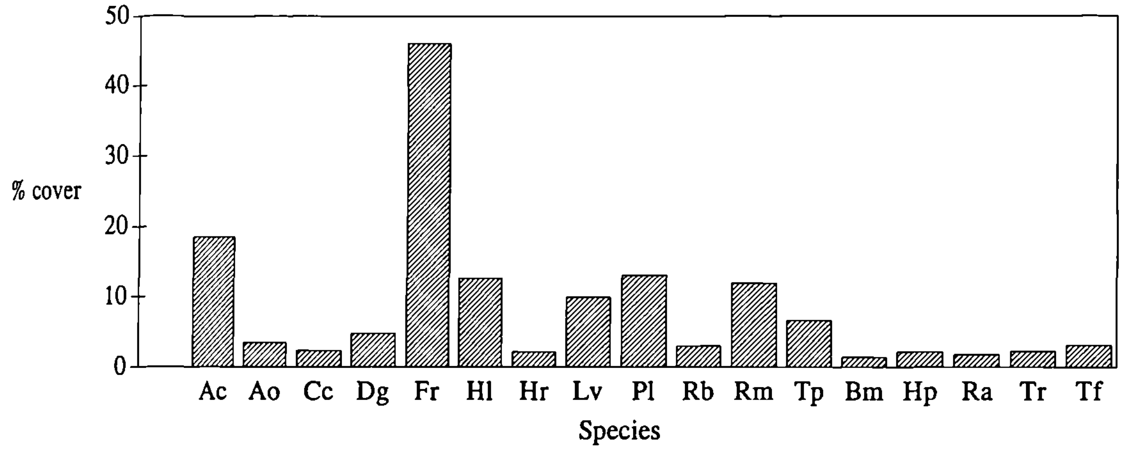
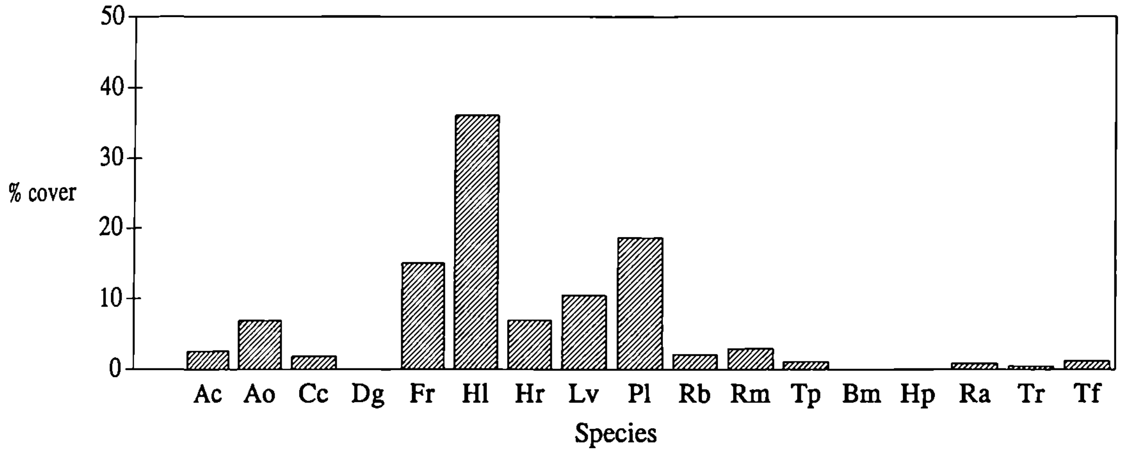


Figure 5.5: Histograms Showing the Mean % Cover of Constant Species at Pennerley Meadows and Merridale School.

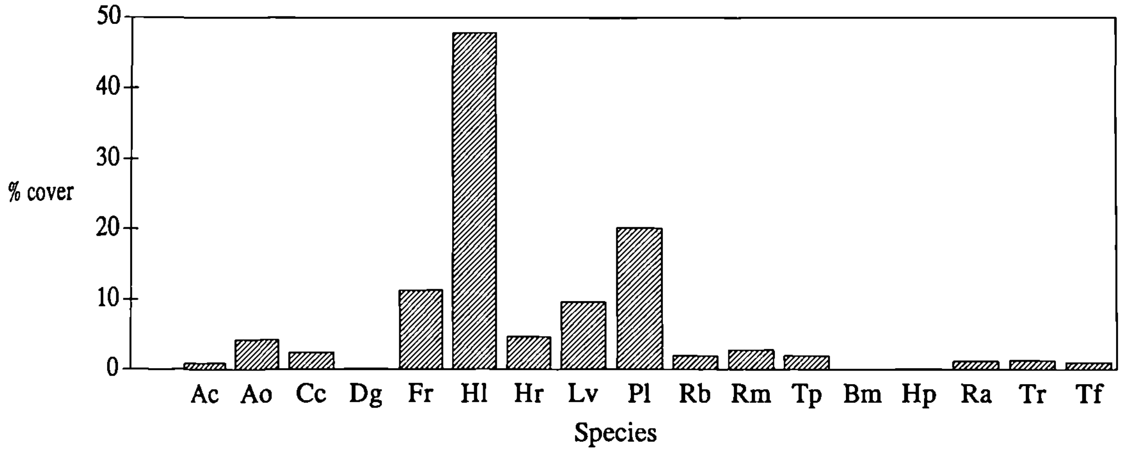
- PENNERLEY MEADOWS (1987)



- MERRIDALE SCHOOL POTATO PLOTS (1988)



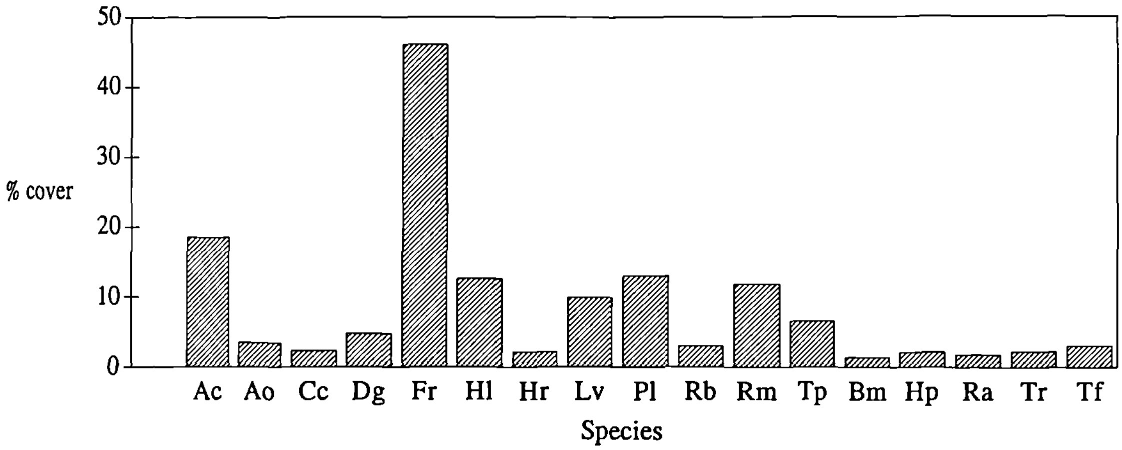
- MERRIDALE SCHOOL UNPLANTED PLOTS (1988)



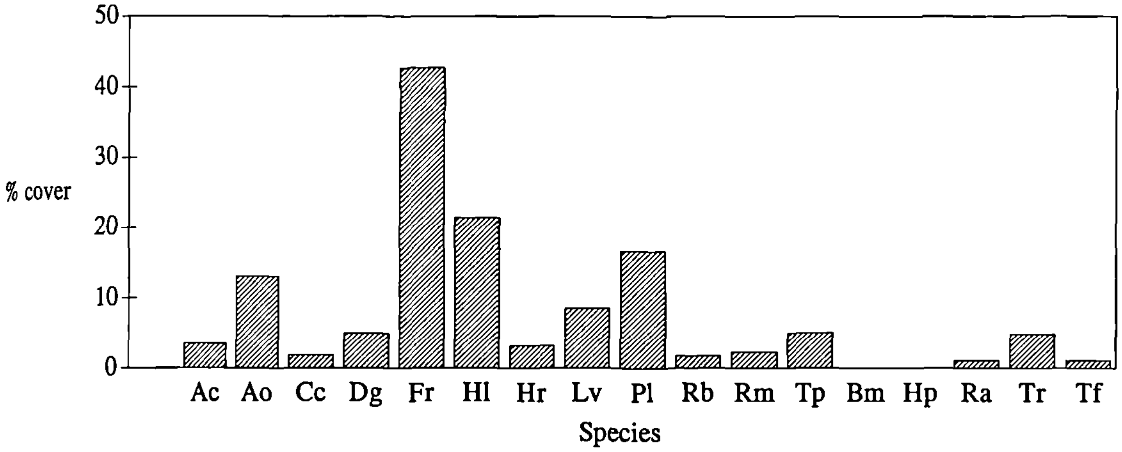
NOTE: Abreviations are used for species names; species are given in same order as shown in Table 5.4.

Figure 5.5 Continued:

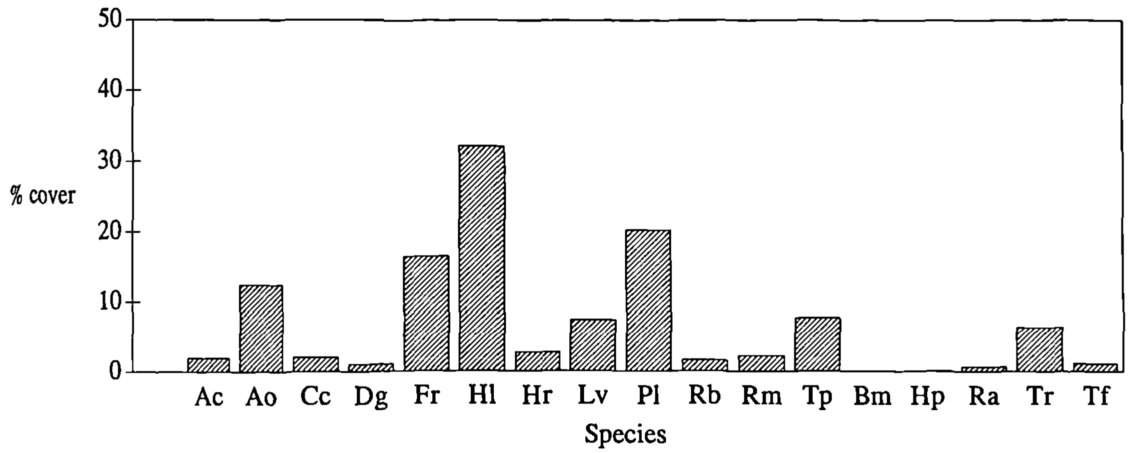
- PENNERLEY MEADOWS (1987)



- MERRIDALE SCHOOL POTATO PLOTS (1989)



- MERRIDALE SCHOOL UNPLANTED PLOTS (1989)



NOTE: Abreviations are used for species names; species are given in same order as shown in Table 5.4.

CHAPTER 6

The Effect of Cropping Prior to Species-rich Grassland Creation on the Standing Crop and Species Composition of the Created Sward

6.0 The Effect of Cropping Prior to Species-rich Grassland Creation on the Standing Crop and Species Composition of the Created Sward

6.1 Introduction

The important relationship between soil fertility and plant species diversity in grasslands, and the need for relatively infertile soils for the creation of diverse grassland communities, has been discussed previously in this report. Some research has been undertaken to investigate methods of reducing soil fertility prior to creation of species-rich grassland and one approach which has been suggested in the literature involves arable cropping on an experimental site before grassland establishment (see Chapter 5). However, there appears to be little practical experience of the use of this technique during habitat creation schemes in this country. The value of cropping with potatoes was assessed in the experiments described in Chapter 5. In Chapter 6 an experiment is discussed in which the relative value of growing a number of different crop species has been investigated.

In the cropping experiment discussed in Chapter 5, variations in the floristic composition of a created grassland sward were used to assess whether prior cropping with potatoes had been beneficial as a method of depleting soil nutrient availability. The experiment described in this chapter used an alternative approach to make this assessment involving the measurement of above ground standing crop of the created sward.

In grassland ecosystems, low standing crop is usually associated with relatively high species diversity (Grime, 1979) and implies a fairly low soil fertility. Conversely high standing crop values are almost invariably associated with low species richness and may be indicative of fertile soils. These relationships have been noted in a range of habitats (eg. Grime, 1979; Olff & Bakker, 1991; Willems, 1980; Wheeler & Giller, 1982; Wheeler & Shaw, 1991; Vermeer & Berendse, 1983; Willis, 1963).

Melman *et al* (1985) considered the measurement of the above-ground standing crop to be a good indication of nutrient availability and such measurements have been used in recent years during studies in which cropping has been investigated as a method of reducing soil nutrient status prior to habitat creation. Marrs (1985), for example, undertook controlled bioassays of test species to study changes in standing crop. These changes he took to relate to variations in nutrient availability in soil from a site which had been cropped prior to attempts to re-establish heathland vegetation. Above-ground standing crop was used in a different way to indicate changes in soil nutrient availability following cropping treatment during the present study.

The underlying objective of the present study is to investigate factors which control the establishment of species-rich grasslands. It seemed sensible, therefore, to investigate the value of cropping as a soil impoverishment technique prior to meadow creation by looking for variations in the created sward. An experiment was therefore established in which the standing crop of the created vegetation and its constituent species was used as a measure of the relative value of cropping with different crop species. As in the controlled bioassay experiments employed by other workers, this approach provides no absolute index of fertility. However, any variations in standing crop between treatment plots might provide an indication of the relative benefit of those treatments in terms of both reducing nutrient availability and increasing the success of grassland establishment.

In addition to testing different crop plants, a treatment comparing the value of adding a nitrogen fertiliser to the crop plants was also introduced in the experiment. It may seem strange to attempt to reduce fertility by adding fertilisers. However, Marrs (in press) has suggested that added nitrogen enhances crop growth and nutrient uptake without building up significantly in soils. The addition of inorganic nitrogen to wheat was found to almost completely exhaust soil phosphorus in long term experiments at Broadbalk (Dyke *et al*, 1983). It seems that the addition of nitrogen fertiliser to crop plants may therefore bring about a greater uptake of other plant nutrients thus leaving the soil more impoverished than if no fertiliser had been applied, and it was based on this principle that the treatment was used during the experiment described here.

The experiment was carried out in field plots established at the Polytechnic's Agricultural Unit, Compton, Wolverhampton. The area set aside for the experiment had previously been maintained as permanent grassland and in recent years it had been mown for hay during July. The grassland had received periodic inputs of inorganic fertilisers and lime to maintain sward productivity although no record remains of the amounts used.

The experimental area was flat with apparently uniform soil conditions throughout and a mean soil pH of 5.5. Prior to the experiment, the area supported a homogeneous species-poor grassland sward dominated by the grasses *Agrostis capillaris*, *Holcus lanatus* and *Festuca spp.*. Herbs were limited to a few common species and included *Bellis perennis*, *Cerastium fontanum*, and *Veronica spp.*

6.2 Methods

6.2.1 Site Preparation and Cropping Methods

During the experiment three test crops were compared: forage maize (Fronica), spring barley (Triumph) and potatoes (Scottish Estemma). A fourth treatment, involving the cultivation of ground as for cropping but then leaving it fallow, was also incorporated to compare the affect of leaching on soil impoverishment with the cropping treatments. A control, in which the existing grassland sward was retained and no hay was strewn, was also used.

As suggested above, a treatment involving the application of a nitrogen fertiliser, was also introduced.

Ten treatments were therefore used during the experiment as follows:

Potatoes	$\pm$N
Barley	$\pm$N
Maize	$\pm$N
Leaching	$\pm$N
Control	$\pm$N

Three replicates of each treatment were established in 3m x 3m plots, positioned randomly in a block. The experimental area therefore had a total area of 270m^2 (Figure 6.1: p. 156).

Before the crop plants were sown, the existing grassland vegetation in all the plots, except the six controls, was killed using glyphosate. This was carried out in April 1987. Once the herbicide had taken effect, the treated plots were rotavated and harrowed using tractor drawn machinery.

The crops were sown into their respective plots on the 4 May 1987 at the following rates:

Barley	160 kg/ha (= 16g/m^2)
Maize	78.4 kg/ha (= 7.84g/m^2)
Potatoes	35 seed potatoes per 3m X 3m plot

Nitrogen was applied as ammonium sulphate at a rate of 150kgN/ha to the appropriate plots on 28 May 1987.

On 2 June 1987 the potato plants were 'ridged up' and the leaching plots were weeded. The leaching plots were subsequently kept weeded.

The crops were harvested on 24 July 1987. The barley, maize and potato plants were cut at ground level and all above ground material removed from the site. The potato tubers were then harvested using a mechanical potato lifter. All the plots (except the controls) were then lightly rotavated to level the ground and produce a suitable seed bed.

6.2.2 Soil Analysis

Although standing crop was used as the main indication of soil fertility, basic chemical analyses were also carried out. Five soil samples were collected from each of the experimental plots to a depth of approximately 12cm. The samples from each plot were combined and mixed. Parameters measured were nitrogen as ammonium and nitrate, available phosphorus and available potassium. Standard analytical methods were used during the analyses (Ministry of Agriculture, Fisheries and Food, 1986).

6.2.3 Meadow Establishment

Pennerley Meadows provided the hay for the experiment. Harvest times and methods are as described in Chapter 5. One big bale, the product of approximately 0.06ha of the donor meadow, was spread evenly over the experimental area. The hay formed a thick (c. 15cm) layer which was allowed to dry for about three weeks before being removed. During the drying period the hay was turned periodically by hand.

6.2.4 Standing Crop Analysis

The standing crop of the created grassland was measured in both 1988 and 1989 using the following procedure:

i) As the 3m x 3m experimental plots were contiguous, only the central 2m X 2m of each was used during the analysis to minimise any treatment overlap or edge effects. The central 2m x 2m of each plot was delimited using rope quadrats and the grassland outside of each quadrat cut and removed from the site (7 July 1988 & 14 July 1989).

ii) The above ground vegetation in each 2m x 2m quadrat was then harvested using shears, placed in a black bag and stored at 5°C until it could be analysed. The whole process took approximately two weeks and analysis of the vegetation in any one plot took place no longer than 36 hours after it was harvested.

iii) In the laboratory the fresh weight of the hay crop from each 2m X 2m plot was recorded. The hay crop from each plot was then roughly mixed and spread out and a random sub-sample (approximately 10%) was picked out from throughout the spread hay.

iv) The sub-sample was separated into its component species and the fresh weight of each species recorded. The combined species fresh weights was equivalent to the sub-sample fresh weight.

v) The individual species samples were dried at 60°C for three days and re-weighed to obtain a dry weight value. The combined species dry weights was equivalent to the sub-sample dry weight.

vi) Using the known fresh weight of the vegetation in each 2m x 2m plot and the sub-sample fresh weight to dry weight ratio, a total dry weight value for each plot was calculated together with a total dry weight value for the individual species making up the sample. These values were then converted into grams per m^2.

6.2.5 Statistical Analysis

As three replicates of each treatment were used, simple statistical tests were employed to assess the level of significance of any apparent variations resulting from the different treatments. Standard errors for the replicates were calculated for all meaned data and plotted as standard error bars on any histograms produced.

Analysis of variance was undertaken using the computer package SPSSx on the PRIME mainframe computer at the Polytechnic. All analyses of variance on standing crop values used transformed data (log n) although analyses using untransformed data failed to produce significantly different results. Analysis of variance of soils analysis results and DECORANA scores (see below) involved the use of untransformed data. A 5% LSD (least significant difference) test (5% LSD = $t \times \sqrt{2s^2/n}$) was used to identify the treatments which produced the results which were proved to be significantly different by analysis of variance.

The large data set generated by the standing crop analysis of individual species was also subjected to Detrended Correspondence Analysis using DECORANA, a computer programme devised by Hill (1979b) and modified and presented by Malloch (1988) in the VESPAN computer software package. DECORANA is based upon the same principles as the Reciprocal Averaging (RA) ordination technique described in Chapter 2 and has generally superseded its use during ecological studies.

DECORANA provided an ordination of the standing crop data for the experimental plots in terms of the species they contain and similarly the recorded species are ordinated in terms of the plots in which they occurred. The former ordination provided an indication of the relative similarity of the experimental plots whilst the latter gave an indication of the factor or factors (environmental gradients) responsible for the variation between plots.

DECORANA, as provided in the VESPAN package, only recognises whole quantitative values above 1. Any species with a total standing crop of less than $0.45g/m^2$ were therefore eliminated from the analysis. This was not considered to effect the results of the analysis significantly as species with quantitative values lower than this figure were generally only present in a few plots. Only the first ordination axis, that representing the most important environmental gradient, was considered although three others of decreasing importance are also produced by the analysis.

6.3 Results

6.3.1 Performance of the Cropping Treatments

In order to understand any differences between the vegetation created in the different plots it is first important to examine the performance of the different crop plants used. Although no quantitative measurements of crop performance or yield were made during the experiment, a number of general observations can be made.

The potatoes grew well in the experimental plots, despite the high density at which they were planted, and the dense above ground growth of the plants seemed to suppress the development of weeds. Although the crop was harvested before its optimum harvest time, the potato tubers had reached a reasonable size, as was noted at Merridale School (Chapter 5), and the harvesting operation produced a good tilth and ideal seed bed for the introduction of donor meadow seeds.

Barley also established and grew well in the test plots. As a spring variety was used only a limited growing period was available although the crop was approaching maturity by the time of the harvest. However, unlike the potatoes, a saleable crop was not produced. Furthermore, the more open nature of the barley crop meant that weeds were able to become established in the plots and ideally some form of weed control would have been implemented to maximise crop growth and nutrient uptake. It was not practicable to remove any below ground material during the harvest and this is perhaps another disadvantage compared to cropping with potatoes.

Unlike the other crops, maize growth in the experimental plots was poor. Many of the plants failed to establish and experience at other sites (Chapter 8) suggests that loss of seed due to feeding birds may have been a primary reason for this. Those plants which did establish failed to show significant growth before it was necessary to harvest the crop and the maximum height achieved was approximately 30cm. The optimum harvest time for maize can be as late as October, depending on the site, and dry matter yield can almost double between late July and mid September (Ministry of Agriculture, Fisheries and Food, 1985). Furthermore, MAFF (1985) indicate that weed competition during the early growth of maize can have a serious effect on yields and the relatively open maize plots encouraged an abundant weed flora.

The limited growth of maize meant that in real terms, the maize plots were very similar to the plots which were left fallow (leaching plots) although the latter were weeded during the cropping season.

6.3.2 Soil Analysis

The chemical analysis of the soil in the experimental plots suggested that there were no significant differences between the treatments in terms of the measured parameters ($p<0.05$)(Table 6.1: p.126). If no standing crop analysis had been undertaken, and conclusions were drawn on the basis of chemical soil analysis results only, it may have been concluded that cropping had no measurable effect on the soil and is consequently of little benefit during habitat creation when undertaken for a single season. However, as will be seen below, the vegetation analysis did reveal significant effects of cropping on soil fertility suggesting that only much more sophisticated chemical analyses would produce comparable results.

The analysis indicated that, despite a history of fertiliser application, the soil present at the site was relatively infertile. This is probably a reflection of the light, sandy nature of the soil which probably facilitates leaching from the surface layers. It is important to bear in mind the relatively infertile starting point when considering the results of the standing crop analysis discussed below, as these may not be applicable to soils with high residual levels of fertility.

6.3.3 Comparison of the Control and Experimental Plots

In the first season following cropping (1988) there were pronounced visual differences between the control and the experimental plots. The control plots, in which the existing vegetation had been retained and which had received no hay from the donor meadow, supported a grass dominated sward in which the overall species diversity was low and, as may be expected, reflected that of the grassland adjacent to the experimental area. Although not markedly taller than the vegetation in the experimental plots in 1988, the vegetation in the control plots was denser with a much higher amount of vegetative biomass. The mean standing crop for the six control plots was higher than that recorded for the other experimental treatments (Table 6.2a: p. 128 & Figure 6.2a: p. 157). Analysis of variance indicated that these differences were statistically significant ($p<0.05$) (Table 6.2c: p. 128).

It is difficult to attribute these differences in standing crop between the control plots and the experimental plots directly to changes in soil fertility brought about by cropping or leaching as the experimental plots supported an immature and open sward. As noted in other created meadows, the amount of vegetative biomass which accumulates in a created meadow in the first year is invariably restricted as the plant species compete strongly for a niche within the new meadow and effort is concentrated on flowering and seed production rather than vegetative spread.

However, by the second season (1989), significant differences still existed between the control plot and the cropped plots in terms of the total standing crop of the grassland vegetation present (Table 6.2b: p. 128 & Figure 6.2b: p. 157). The standing crop of the vegetation in the leaching plots had, however, increased whilst that of the control plots had fallen by approximately 11% such that the differences between them were no longer significant (Table 6.2c: p. 128).

The differences apparent in the second year may well reflect reductions in soil fertility brought about by cropping as by this time the created meadow vegetation was well established and a closed sward was present in which significant vegetative spread was noted.

6.3.4 Comparison of the Cropping and Leaching Treatments

There were distinct visual differences between the created vegetation in the different cropping treatments in 1988. In particular the plots cropped with potatoes and barley supported a grassland vegetation which seemed less coarse than that of the leaching and maize plots, which was mainly a result of a lower abundance of weed species and a less vigorous growth of the introduced species, particularly *Leucanthemum vulgare*. These inter-treatment differences are potentially of more importance than the differences with the control plot discussed above as they could reflect variations in soil nutrient availability brought about by the different cropping treatments.

The differences noted in the appearance of the created sward in the different treatment plots were reflected in the mean total standing crop data for the plots (Table 6.2a: p. 128). It is apparent that in 1988 there was little difference between the mean standing crop of the vegetation growing in the leaching and maize plots. It has been suggested above that the growth of the maize during the cropping season (1987) was particularly poor and that consequently the leaching and maize plots were in effect similar in terms of preparation.

The potato and barley plots, however, supported vegetation with a lower standing crop than the leaching/maize plots. This difference is clear when the control plot data is masked and the standing crop data for the other plots are plotted (Figure 6.3a: p. 158). It seems possible that these differences, which in the case of barley were significant ($p<0.05$) (Table 6.3: p. 129), are a result of the effect that the cropping treatments had on the experimental soil, and possibly on soil nutrient availability.

The visual differences in the vegetation supported in the different plots persisted in the second year. However, the mean standing crop of the vegetation in the maize plots had declined whilst that in the barley had increased so that the barley, potatoes and maize plots were approximately equal. Analysis of variance indicated that there was no longer a significant difference between them (Table 6.3: p. 129 & Figure 6.3b: p. 158). The mean standing crop of all three of the cropping treatments were significantly lower than the leaching plots. This is a difficult trend to explain although it should be borne in mind that, in statistical terms, the difference between the mean standing crop values for the individual treatments recorded in the two years was not significant and so such variation from year to year may be expected to occur by chance.

6.3.5 Effects of the Nitrogen Treatment on Total Standing Crop

The objective of adding nitrogen to some plots has been described above. Essentially it was to test the hypothesis that by adding nitrogen, a relatively mobile major plant nutrient, and encouraging an improved crop growth, a greater amount of the more immobile nutrients such as phosphorus, will be removed from the soil. If this hypothesis is true it would be reflected by lower standing crops in the plots to which nitrogen had been added than those which remained unfertilised.

Standing crop data are presented in Table 6.4 (p. 130) and these data are presented graphically in Figures 6.4a & b (p. 159). In 1988 the mean standing crop of the vegetation growing in the control, leaching and maize plots showed little variation in relation to the addition on nitrogen fertiliser and analysis of variance indicated that there were no significant differences between these treatments (Table 6.5a: p. 131). However, the mean standing crop in the potato and barley plots to which nitrogen had been added was significantly higher from that in the potato and barley plots which had remained unfertilised ($p<0.05$) (Table 6.5a: p. 131).

It is apparent therefore, that the addition of nitrogen fertiliser failed to reduce soil fertility indirectly as hypothesised, and so reduce the standing crop of the created meadow vegetation. Indeed the opposite effect was seen in the plots cropped with potato and barley, where higher standing crops were noted in the created vegetation in the plots to which fertiliser had been added. This may indicate that residual levels of nitrogen fertiliser remained in the soil following harvest of the potato and barley from the fertilised plots; probably a reflection of the relatively high levels of nitrogen applied (150kg/ha) and the short cropping season. However, the fact that the standing crop of the vegetation in the potato and barley plots to which nitrogen was added was not significantly different to that in the other treatment plots (Table 6.5b: p. 131) further indicates that cropping with potatoes and barley, without the addition of fertiliser, did have an impoverishing effect on the experimental soils.

By the second year the situation had become somewhat confusing (Figure 6.4b; p. 159). The mean standing crop in all treatments, with the exception of maize, was not significantly different with regard to fertiliser application. This may be a result of the residual nitrogen in the soil of the fertilised plots having been used up or lost from the soil by leaching but if this were the sole explanation, a drop in the mean standing crop of vegetation in the fertilised plots may have been expected rather than the observed increase in the mean standing crop of the unfertilised plots. The situation is obviously complex although it is possible that growing conditions in 1989 brought about a generally higher biomass yield than in 1988.

The result for maize in the second year, and the apparently significant difference between fertilised and unfertilised plots is not easy to explain and appears to be anomalous.

6.3.6 Effects of the Treatments on Sward Composition and Diversity

During the biomass analyses undertaken in 1988 and 1989 the standing crop of the constituent species within each plot was calculated in addition to the total standing crop for each plot. These data are presented in Table 6.6 (p. 132).

This large data set was subjected to Detrended Correspondence Analysis using DECORANA. This produced four axes with corresponding eigenvalues of 0.57 (axis 1), 0.26 (axis 2), 0.08 (axis 3) and 0.06 (axis 4). The results of axis 1 of the stand ordination for this analysis are presented in the form of a nested mean table (Table 6.7: p. 142).

It is clear that there is very little difference between the overall means for 1988 and 1989 (mean column 1) or for the means for individual treatments in 1988 compared with 1989 (mean column 2). Analysis of variance of the DECORANA ordination scores indicated that the data for 1988 are not significantly different to those for 1989. There were, however, greater differences between the mean scores for the treatments in any one year (mean column 3) and these proved to be significant ($p < 0.05$).

Table 6.8 (p.143) shows the ranking of treatments according to ascending ordination score. In both 1988 and 1989 the control plot is towards the higher end of the ordination axis whilst, in relative terms, the other treatments are arranged towards the lower end of the axis. This reflects the results obtained for the total standing crop analysis in which the control plot was significantly different from the other treatments in terms of the mean total standing crop. The ordination results thus confirm that the control plot varies from the other treatments not solely in terms of total standing crop, but also in terms of species composition.

It is clear from the results presented in Table 6.8 (p. 143) that there are other parallels with the results of the total standing crop analysis. The mean scores for the leaching and maize treatments were approximately equal in both 1988 and 1989, as were the scores for the barley and potato treatments, the latter pair being positioned lower down the axis than the former. This suggests that the barley and potato plots are, on average, more different from the control than the leaching and maize plots in terms of species composition as well as total standing crop.

In order to interpret these differences in species composition it is useful to consider the species ordination (Table 6.9: p. 144). The environmental gradient responsible for the stand ordination is the same as that responsible for the species ordination.

There is a degree of 'noise' in the species ordination as a result of the positioning of species which were very scarce within the experimental plots. Therefore, for ease of interpretation, species which were present in more than one plot have been typed in bold in Table 6.9 (p.144) whilst those present in only one plot are typed in normal typeface.

Table 6.9 (p. 144) shows that species positioned towards the higher end of the axis (i.e. scores greater than approximately 100) include those associated with the control plot vegetation. The lower end of the axis (i.e. scores less than approximately 7) includes species associated with the vegetation at the donor meadow. The middle section of the axis includes a range of species many of which may be considered to be indicative of disturbance such as *Rumex crispus* and *Cirsium arvense*.

The axis therefore represents a gradient from one relatively stable type of vegetation to another relatively stable type of vegetation through a transition of disturbance related vegetation. One objective of strewing hay was to change the vegetation from that already present at Compton to something reflecting that present at Pennerley Meadows. It follows, therefore, that plots positioned towards the bottom end of the axis of the stand ordination support a vegetation type which, in terms of the objectives of the experiment, is more desirable because it is more similar to that of the donor vegetation.

There are some contradictions in this interpretation of the species ordination. *Agrostis capillaris* for example, is positioned towards the top end of the axis although it is a constant species in the Pennerley Meadows sward. However, this species is also characteristic of the control plot vegetation. Indeed, at the Compton site, it is more characteristic of the control plot than it is of the vegetation in the other experimental plots as it had yet to become established in significant quantities. This is clearly illustrated if the standing crop data for *Agrostis capillaris* are plotted (Table 6.10: p. 145; Figure 6.5a & b: p. 160).

If this interpretation of the species ordination is accepted, the potato plots support, on average, the most desirable vegetation, in terms of species composition (species diversity and relative standing crop of individual species), followed by the barley plots, the leaching plots, the maize plots and lastly the control plots. This ordering of treatments was apparent in both 1988 and 1989.

The total standing crop results indicated that the barley plots supported the vegetation with the lowest standing crop, implying that this cropping treatment had been more successful than potatoes at reducing nutrient availability. The DECORANA analysis, on the other hand, suggested that pre-cropping with potatoes gave better results than did barley. It may therefore be the case at Compton that at low levels, nutrient availability is not the only factor influencing species diversity and composition. However analysis of variance indicated that, in both the total standing crop analysis and the DECORANA stand ordination, the results for the potato and barley plots were not significantly different from one another.

It is of interest that the ordination results indicate that the maize plots support a less "desirable" vegetation than did the leaching plots. As indicated above (section 6.3.1), the growth of the maize was poor during the cropping season. However, this fact alone should not account for a difference from the leaching plots. The fact that the maize plots were not weeded whilst the leaching plots were appears to have resulted in the persistence of a higher number of weed species following hay strewing such that the maize plots supported a vegetation more different from the potato and barley plots than were the leaching plots, hence its positioning higher up the axis. Analysis of variance indicated, however, that the differences present between the maize and leaching treatments were not significant.

A combined ranking of treatments in both 1988 and 1989 according to ordination score is presented in Table 6.11 (p. 146) which shows that for both the potato and barley treatments, the 1989 results had lower scores on axis 1 than the 1988 results. This is an interesting ranking as it indicates that the potato and barley plots were more different from the control vegetation in the second year than in the first. Therefore, if the premise is accepted that a low ordination score represents affinity with the donor vegetation, the vegetation in the potato and barley plots was, on average, improving with time. This trend was also apparent for the leaching and maize treatments which both had lower ordination scores in the second year.

These results suggest that sward composition and similarity to the donor vegetation was therefore not solely a product of the initial introduction and establishment of species with hay. Once established the similarity of the created vegetation with that of the donor increased with time.

If the nitrogen treatment is taken into consideration (Table 6.12: p.147) it can be seen that in both years the plots for each particular treatment which received nitrogen were positioned higher on the axis than their respective unfertilised plots suggesting that the addition of nitrogen was detrimental in terms of sward diversity and species composition. The only exception to this was the leaching plots in 1989 where the fertilised plots were lower on the axis than the unfertilised plots, however, the scores were very similar with no significant difference between them indicated by analysis of variance.

It is clear that the control plots strongly influence the stand ordination and the complete DECORANA analysis was therefore repeated with the control plots masked (Table 6.13: p. 148).

It is apparent that the results for the two years have been separated on the axis (mean column 1), with the overall mean for year 1 being positioned towards the top end of the axis whilst the overall mean for 1989 positioned towards the lower end. In the corresponding species ordination (Table 6.14: p. 149), higher ordination scores ($> \approx 100$) are attributed to what may loosely be described as the weed species in the created vegetation. As before, species associated with the more stable Pennerley Meadows vegetation have lower ordination scores ($< \approx 100$).

The axis may therefore represent a transition from relatively disturbed conditions, in which weeds thrive, to more stable conditions i.e. a distinction is being drawn between the more disturbed conditions prevalent in the experimental plots in 1988 and the more stable conditions in 1989. Weed species, such as those characteristic of cultivation including *Agrostis gigantea*, *Polygonum aviculare* and *Tripleurospermum inodorum*, which benefited from the disturbance resulting from site preparation, displayed a marked decline in abundance in the treatment plots in the second year. These results uphold the previous interpretation that the created vegetation is improving with time.

It is of interest that *Rhinanthus minor*, a species generally associated with established meadows and characteristic of Pennerley Meadows, is positioned towards the top of the ordination, amongst the weed species which were abundant in year 1. There are possibly two reasons for this.

Firstly, the annual, hemi-parasitic life form of this species means that its success is dependent upon its ability to establish well from seed and being an abundant member of the donor meadow community, large quantities of fresh seed would have been introduced to the experimental plots with the strewn hay. It is therefore not surprising that it was found in relatively high quantities in 1988.

Secondly, 1989 seemed to be a generally 'bad year' for this species in all of the created meadows in Wolverhampton, it being present at lower frequencies that previously recorded. This could have related to seedling mortality due to late frosts experienced in that year although it is also apparent that *R. minor* exhibits natural fluctuations in abundance from year to year (Grubb *et al*, 1982; Trueman, pers. comm).

These two factors resulted in a high abundance of *R. minor* in the experimental plots in the first year but a significantly lower abundance in the second year of the experiment. It thus displayed the characteristic pattern of decline in abundance demonstrated by the weed species present in the experimental plots hence its positioning towards the top end of the axis.

It is also of interest that, with the control plots removed from the analysis, *Agrostis capillaris* is positioned towards the bottom of the axis indicating its association with the donor meadow vegetation.

6.3.7 Variations in the abundance of individual species according to cropping treatment.

It is of value to consider the relative abundance of individual species according to the various treatments. The data presented in Table 6.6 (p. 132) are summarised in Table 6.15 (p. 150) to show mean standing crop data for individual species according to cropping treatment, but without regard to nitrogen treatment, for the two years of the experiment.

Several groups of species are recognisable in Table 6.15 (p. 150):

a) Species which may or may not have been introduced with the hay but which were only recorded in one or two of the total of thirty experimental plots and whose presence was apparently random and not related to a particular cropping treatment. Species falling into this category are *Daucus carota*, *Euphrasia officinalis agg.*, *Hieracium pilosella*, *Senecio jacobea*, *Sonchus asper*, *Veronica arvensis*, *Vicia sativa* and *Vulpia bromoides*.

b) Weed species which benefited as a result of the cultivation used during site preparation for cropping but are not otherwise treatment specific. These include *Cirsium arvense*, *Elymus repens*, *Epilobium ciliatum*, *Juncus bufonius*, *Polygonum aviculare*, *Rumex crispus*, *R. obtusifolius* and *Tripleurospermum inodoratum*.

c) Species which have not been introduced with the hay but were present at the experimental site prior to the experiment. They have either persisted in the control plots only or have invaded the experimental plots but do not display any form of treatment specificity. These include *Galium aparine*, *Heracleum sphondylium*, *Bromus mollis*, *Holcus mollis*, *Poa trivialis* and *Quercus robur*

d) The crop species Barley (*Hordeum vulgare*) and potato (*Solanum tuberosum*), several individuals of which germinated/persisted in their respective cropped plots following harvest.

e) Three species, *Agrostis capillaris* (discussed above Table 6.10: p. 145; Figure 6.5a & b: p.160), *Dactylis glomerata* (Figure 6.6a & b: p. 161) and *Rumex acetosa* (Figure 6.7a & b: p. 162), were abundant in the control plot but, despite being present in the source meadow, their relative abundance in the experimental plots was low. *D. glomerata* and *R. acetosa* are similar to *A. capillaris* being common grassland species and frequent members of both the original Compton grassland sward and Pennerley Meadows. All three have yet to fully establish in the experimental plots but it is likely that individuals which were present in the experimental plots were introduced with the hay. None of these species displayed any preference for specific treatments.

f) *Agrostis gigantea* (Figure 6.8a & b: p. 163) displayed the opposite trend to e), being present in the control plot but much more abundant in the cultivated plots. By the second year, it had declined dramatically in the treatment plots although it persisted in the control. The variation between the two years of the survey for this species proved to be significant after analysis of variance ($p < 0.05$, Table 6.16: p. 151).

g) A group of species, probably introduced with the hay, were present predominantly in the experimental plots as opposed to the control plots but displayed no treatment specificity. These included *Cerastium fontanum, Centaurea nigra, Cynosurus cristatus, Festuca rubra, Leucanthemum vulgare, Lolium perenne, Luzula campestris, Plantago lanceolata, Ranunculus spp., Taraxacum spp., Trifolium dubium, T. pratense, Trifolium repens* and *Trisetum flavescens*.

h) The remaining species all displayed some preference for particular treatments.

Holcus lanatus was more abundant in the control, leaching and maize plots than the barley and potato plots (Figure 6.9a & b: p. 164) and this proved to be a significant difference after analysis of variance (Table 6.17a: p. 152). Furthermore, this species displayed a markedly lower standing crop in the unfertilised potato, barley and maize plots than the fertilised plots (Figure 6.9c: p. 165). This difference also proved to be significant ($p < 0.05$, Table 6.17b: p. 152) although it only persisted into the second year as a significant difference in the maize plots (Figure 6.9d: p. 165).

The problems experienced in the early years of created meadows due to the abundance of *H. lanatus* have been discussed earlier in this report (Chapter 3). The cropping treatments, particularly with potatoes and barley without nitrogen addition therefore appear to have a positively beneficial effect by suppressing the abundance of this species.

Anthoxanthum odoratum was more abundant in the cropped plots than the leaching or control (Figure 6.10a & b: p. 166) although these differences, with the exception of the potato plots, proved not to be significant. There was, however, a significant increase in the standing crop of this species between 1988 and 1989, showing that the species had been successfully introduced to the experimental plots and was thriving.

Hypochoeris radicata and *Rhinanthus minor* both had a higher mean standing crop in the barley and potato treatments (Figures 6.11a & b: p. 167, 6.12a & b: p. 169). Some of these differences proved to be significant ($p<0.05$, Tables 6.18: p. 153 & 6.19: p.154). It is also interesting that both of these species showed a negative relationship with the addition of nitrogen in the first year in some of the cropping treatments (Figures 6.11c: p. 168 & 6.12c: p. 170) although these were not statistically significant and generally failed to persist into the second year (Figures 6.11d: p. 168 & 6.12d: p. 170).

The marked decline displayed by *R. minor* between 1988 and 1989, the reasons for which have been postulated above, is clearly shown in Figures 6.12a-d (pp. 169 - 170). This decline was significant in the leaching, potato and barley plots ($p<0.05$, Table 6.20: p. 154).

6.4 Discussion

To some extent the overall results of the experiment were predictable. Cultivation was bound to change the vegetation relative to the uncultivated controls, and the input of Pennerley Meadows seed was bound to influence the nature of this new vegetation as has been shown in previous experiments.

It is interesting, however, that as a result of the cropping treatments, particularly cropping with potatoes and barley at this site, there was some measurable level of success at rendering the soil more suitable for the subsequent grassland creation. The overall standing crop of the created vegetation was reduced in the cropped plots suggesting some form of depletion of the soil. Whether or not this relates to direct removal of nutrients from the soil is not clear. The crude chemical analyses carried out suggested that there were no significant differences in soil chemistry in terms of the major plant nutrients nitrogen, phosphorus and potassium. Chemical analyses do have their limitations, however, and these have been discussed previously.

Lower standing crops in the treatment plots compared to the control plots might have been predicted in the first year as a newly establishing sward is relatively open with limited vegetative growth. The 'centre of gravity' of a newly establishing grassland sward tends to be higher above the ground than in that of a well established sward as effort is put into flowering and seed production (cf. arable field). As a sward matures the 'centre of gravity' moves down as a higher proportion of vegetative biomass develops until the situation in a mature grassland sward where the vegetative growth constitutes the greatest proportion of a swards standing crop. It is therefore perhaps not ideal to measure the success of a created meadow by comparing its species composition and standing crop in the first year with that of an established grassland.

The variability between the different cropping treatments in the first (and also in the second) year is of more interest however. The assumption made that the experimental site was homogeneous in terms of its edaphic conditions was borne out by the chemical analyses undertaken. The treatment plots were prepared in exactly the same way and varied only in the crops that were actually grown. Hay was introduced from a generally homogeneous donor and spread in a random way to give an approximately equal cover in the experimental plots. Therefore, the differences in the standing crop of the created sward noted are likely to relate to changes brought about by the different cropping treatments. The lower standing crop in the barley and potato plots when compared to the leaching and maize plots suggest some form of depletion of the soil as a result of cropping. Coupled with the greater species diversity in the potato and barley plots, the results of the experiment provide an indication that in some circumstances, cropping prior to meadow creation may be beneficial, even if only undertaken for a single season.

Similar conclusions were reached by Marrs (1985) during his investigations of the effect of cropping on soil fertility at Ropers Heath. Crops were grown on Ropers Heath for three years between 1980 and 1982 (*Hordeum vulgare* in 1980 and *Secale cereale* in 1981 and 1982) and using a comparative bioassay technique Marrs found that both yield and nutrient content were lower in test plants (*Lolium perenne*) grown on soils which had been cropped. Marrs took this to indicate that cereal cropping had reduced the fertility of the soil at Roper's Heath and he found that this reduction was detectable after only one year of cropping.

Ash *et al* (1992) hold a different view, however, suggesting that cropping on most soils would take many decades to be effective at reducing soil fertility.

It is probable that it may take several years to detect significant changes in soil fertility by cropping on fertile soils. Many urban soils, such as those investigated by Ash *et al* (1992) fall into this category. Fortunately the soils at the Compton experimental site were relatively infertile prior to the experiment. It is arguable that sites with rich soils are fundamentally inappropriate for meadow creation, even if techniques to impoverish soils can be maintained over prolonged periods.

It is apparent that the effectiveness of the cropping treatment is dependent on the crop used. On the basis of total standing crop of the created grassland sward, barley proved to be the most effective at nutrient depletion in this experiment. However, DECORANA provide some evidence that the grassland established on the potato plots may be more desirable in terms of species composition. This is probably due in part to the effective way in which the potato foliage suppresses weed development. Furthermore, the soil in the potato treatments did, following harvest, have a finer tilth and produce an ideal seed bed for subsequent seeding.

Maize proved to be no more effective at impoverishing the soil at the experimental site than natural leaching. Maize is used in Holland for the same purposes, however here tillage occurs for several seasons (Londo, 1977) and so the crop is presumably allowed to grow to maturity.

The addition of nitrogen to the crops during the experiment failed to reduce the standing crop of the subsequently created grassland. The opposite effect was noted in the potato and barley treatments. The quantities of nitrogen applied during the study were high and it is possible that the higher standing crop of grassland established in fertilised potato and barley plots was a result of residual nitrogen in the soil following harvest. However, Marrs (1985) found that a greater yield and nutrient content were recorded in a test crop (*Lolium perenne*) where additions of inorganic nitrogen had been made and that the addition of nitrogen did not have a residual effect in the short term despite a low (20%) apparent fertiliser recovery (ie. the amount of nutrient recovered expressed as a percentage of fertiliser added). He suggests that the 80% of the added fertiliser unaccounted for was lost through leaching, decomposition or was incorporated into the soil organic matter.

The results of the standing crop analysis when nitrogen treatments are taken into account did re-emphasise the value of growing crops prior to meadow creation, however. The standing crop of the vegetation established in the potato and barley plots which were not fertilised was, in the first year following cropping, significantly lower than that in the leaching and maize plots.

Improvements were noted in all of the treatment plots in the second year of the experiment (1989) in terms of species composition and diversity, despite increases in standing crop in some plots. These results again give an indication that provided the correct range of species are introduced at seeding, and an appropriate management regime is implemented, the 'quality' of created grassland vegetation can increase with time. It is clear that one of the main improvements in the created vegetation in the second year was a reduction in the abundance of weed species. It is perhaps not surprising that there should be a larger arable weed population in the first year after cropping as the disturbance resulting from cultivation favours such species. The results do suggest however that the weed flora produced at Compton in the first year was not likely to have long term affects on the vegetation.

In conclusion, the experiment described in this chapter demonstrates that cropping prior to grassland creation on some sites can reduce the availability of plant nutrients in the soil. The benefits may be reflected in both reduced standing crop and an improved species composition in the created sward. Furthermore, cropping does not necessarily have to be carried out for many years for these benefits to become apparent. Cropping with some crop types (eg. potatoes) has the additional benefit of producing an ideal seed bed for subsequent meadow seeding whilst producing a saleable crop which could offset some of the other costs of habitat creation. It is recommended that its use is more widely investigated and applied during grassland creation schemes.

TABLES

Table 6.1: Soil Analysis Results for the Plots in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton.

Treatment		NO_3 (mg/kg dry soil)				
		Replicates			Mean	S.E.
		A	B	C		
Control	+N	0.5	0.5	1.1	0.70	0.20
	-N	0.5	1.5	1.5	1.17	0.33
Leaching	+N	0.5	0.5	0.5	0.50	0.00
	-N	0.5	0.5	0.5	0.50	0.00
Potatoes	+N	0.5	0.5	1.0	0.67	0.17
	-N	1.4	0.5	0.5	0.80	0.30
Barley	+N	0.5	0.5	0.5	0.50	0.00
	-N	0.5	0.5	0.5	0.50	0.00
Maize	+N	0.5	1.1	0.5	0.70	0.20
	-N	0.5	0.5	0.5	0.50	0.00

Treatment		NH_4 (mg/kg dry soil)				
		Replicates			Mean	S.E.
		A	B	C		
Control	+N	3.0	3.8	2.2	3.00	0.46
	-N	1.7	1.5	1.1	1.43	0.18
Leaching	+N	2.2	1.3	2.6	2.03	0.38
	-N	1.5	2.2	0.5	1.40	0.49
Potatoes	+N	3.4	1.5	2.0	2.30	0.57
	-N	1.4	2.1	2.2	1.90	0.25
Barley	+N	2.4	1.5	1.7	1.87	0.27
	-N	1.7	2.1	1.5	1.77	0.18
Maize	+N	2.7	0.5	0.5	1.23	0.73
	-N	1.7	1.6	1.6	1.63	0.03

Note that in the above table a value of 0.5 is used where analysis produced a result of <1.0.

Table 6.1 Continued:

Treatment		Available Phosphorus (mg/l)				
		Replicates A	Replicates B	Replicates C	Mean	S.E.
Control	+N	14.0	16.0	26.0	18.67	3.71
	-N	9.0	19.0	18.0	15.33	3.18
Leaching	+N	9.0	18.0	22.0	16.33	3.84
	-N	12.0	22.0	21.0	18.33	3.18
Potatoes	+N	8.0	12.0	24.0	14.67	4.81
	-N	4.0	6.0	17.0	9.00	4.04
Barley	+N	10.0	7.0	14.0	10.33	2.03
	-N	14.0	8.0	14.0	12.00	2.00
Maize	+N	9.0	33.0	19.0	20.33	6.96
	-N	12.0	8.0	17.0	12.33	2.60

Treatment		Available Potassium (mg/l)				
		Replicates A	Replicates B	Replicates C	Mean	S.E.
Control	+N	65.0	58.0	90.0	71.00	9.71
	-N	72.0	83.0	100.0	85.00	8.14
Leaching	+N	58.0	68.0	69.0	65.00	3.51
	-N	47.0	66.0	86.0	66.33	11.26
Potatoes	+N	65.0	73.0	78.0	72.00	3.79
	-N	65.0	66.0	11.0	47.33	18.16
Barley	+N	60.0	50.0	76.0	62.00	7.57
	-N	75.0	44.0	104.0	74.33	17.32
Maize	+N	61.0	137.0	100.0	99.33	21.94
	-N	72.0	38.0	85.0	65.00	14.01

Note that in the above table a value of 0.5 is used where analysis produced a result of <1.0.

Table 6.2a: Table Summarising Total Standing Crop Data for the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
(nitrogen treatment not shown).

Treatment	Standing Crop (g/m^2)							
	Replicates						Mean	S.E.
	A	B	C	D	E	F		
Control	718.44	684.76	946.47	631.58	901.55	980.51	810.55	± 61.10
Leaching	721.68	480.74	593.04	505.49	706.22	533.33	590.08	± 42.09
Potatoes	743.33	544.49	586.92	460.61	392.34	225.60	492.22	± 72.30
Barley	462.57	499.25	549.30	302.35	335.49	368.30	419.54	± 40.19
Maize	632.07	405.63	901.99	574.36	571.31	487.79	595.53	± 69.27

Table 6.2b: Table Summarising Total Standing Crop Data for the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
(nitrogen treatment not shown).

Treatment	Standing Crop (g/m^2)							
	Replicates						Mean	S.E.
	A	B	C	D	E	F		
Control	617.98	662.96	927.15	345.99	850.00	903.44	717.92	± 90.73
Leaching	588.71	741.40	681.44	548.28	668.29	590.98	636.52	± 29.54
Potatoes	820.95	486.44	329.68	320.83	525.54	450.34	488.96	± 75.54
Barley	463.78	568.67	497.26	559.95	269.73	564.32	487.29	± 46.84
Maize	480.76	556.20	864.10	245.05	411.00	460.18	502.88	± 83.78

Table 6.2c: Tables Showing Mean Values of Log Transformed Data and Significant Differences Between the Control Plots and Cropping Treatments in Terms of Total Standing Crop Identified by Analysis of Variance ($p<0.05$, 5%LSD = 0.12, n = 6).
C = Control; L = Leaching; P = Potatoes; B = Barley; M = Maize;
+ = Significant Difference.

Treatment	1988	1989
Control	2.90	2.83
Leaching	2.77	2.80
Potatoes	2.66	2.67
Barley	2.61	2.68
Maize	2.76	2.69

YEAR	C&L	C&P	C&B	C&M
1988	+	+	+	+
1989		+	+	+

Table 6.3: Tables Showing Mean Values of Log Transformed Data and Significant Differences (+) Between Cropping Treatments (Total Standing Crop) Identified by Analysis of Variance ($p < 0.05$, 5%LSD = 0.12, n=6)
(control plots masked).

L = Leaching, P = Potatoes, B = Barley, M = Maize.

Treatment	1988	1989
Control	masked	masked
Leaching	2.77	2.80
Potatoes	2.66	2.67
Barley	2.61	2.68
Maize	2.76	2.69

YEAR	L&P	L&B	L&M	P&B	P&M	B&M
1988		+				+
1989	+	+	+			

Table 6.4: Summary Table Showing Total Standing Crop for the Different Treatments in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton.

Treatment			Standing Crop (g/m²)				
			Replicates			Mean	S.E.
			A	B	C		
Control	1988	+N	718.44	684.76	946.47	783.22	± 82.20
		-N	631.58	901.55	980.51	837.88	±105.64
	1989	+N	617.98	662.96	927.15	736.03	± 96.44
		-N	345.99	850.00	903.44	699.81	±177.58
Leaching	1988	+N	721.68	480.74	593.04	598.49	± 69.61
		-N	505.49	706.22	533.33	581.68	± 62.79
	1989	+N	588.71	741.40	681.44	670.52	± 44.41
		-N	548.28	668.29	590.98	602.52	± 35.12
Potatoes	1988	+N	743.33	544.49	586.92	624.92	± 60.46
		-N	460.61	392.34	225.60	359.52	± 69.80
	1989	+N	820.95	486.44	329.68	545.69	±144.88
		-N	320.83	525.54	450.34	432.24	± 59.78
Barley	1988	+N	462.57	499.25	549.30	503.71	± 25.14
		-N	302.35	335.49	368.30	335.38	± 19.04
	1989	+N	463.78	568.67	497.26	509.90	± 30.93
		-N	559.95	269.73	564.32	464.67	± 97.48
Maize	1988	+N	632.07	405.63	901.99	646.56	±143.47
		-N	574.36	571.31	487.79	544.48	± 28.36
	1989	+N	480.76	556.20	864.10	633.69	±117.25
		-N	245.05	411.00	460.18	372.08	± 65.08

Table 6.5a: Tables Showing Mean Values of Log Transformed Data and Significant Differences (+) Between Nitrogen Treatments (Total Standing Crop) Identified by Analysis of Variance (p<0.05, 5%LSD=0.17, n=3).

YEAR	TREATMENT	+N	-N
1988	CONTROL	2.89	2.92
	LEACHING	2.77	2.76
	POTATOES	2.79	2.54
	BARLEY	2.70	2.52
	MAIZE	2.79	2.74
1989	CONTROL	2.86	2.81
	LEACHING	2.83	2.78
	POTATOES	2.71	2.63
	BARLEY	2.71	2.64
	MAIZE	2.79	2.56

YEAR	TREATMENT	±N
1988	CONTROL	
	LEACHING	
	POTATOES	+
	BARLEY	+
	MAIZE	
1989	CONTROL	
	LEACHING	
	POTATOES	
	BARLEY	
	MAIZE	+

Table 6.5b: Significant Differences (+) Between Cropping Treatments (Total Standing Crop) Identified by Analysis of Variance (p<0.05, 5%LSD=0.17, n=3).
Mean Values of Log Transformed Data given in Table 6.5a.

C = Control; L = Leaching; P = Potatoes; B = Barley; M = Maize

YEAR		C&L	C&P	C&B	C&M	L&P	L&B	L&M	P&B	P&M	B&M
1988	+N			+							
	-N		+	+	+	+	+			+	+
1989	+N										
	-N		+	+	+			+			

Table 6.6: Table Showing Standing Crop Data for Plant Species Recorded During the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (values in g/m²).

Treatment	Control	+N	Control	+N	Control	+N	Control	+N
Replicate	A		B		C		Mean	
Species / Year	1988	1989	1988	1989	1988	1989	1988	1989
Agrostis capillaris	411.49	386.72	468.55	445.97	427.50	441.62	435.85	424.77
Agrostis gigantea	-	-	3.17	9.42	5.05	-	2.74	3.14
Anthoxanthum odoratum	2.90	2.98	-	4.93	-	-	0.97	2.64
Bromus mollis	-	-	-	-	-	-	-	-
Centaurea nigra	-	-	-	-	-	-	-	-
Cerastium fontanum	-	-	-	0.15	-	-	-	0.05
Cirsium arvense	-	-	-	-	-	-	-	-
Cynosurus cristatus	-	-	-	-	-	-	-	-
Dactylis glomerata	0.10	-	2.59	0.62	15.80	7.19	6.16	2.60
Daucus carota	-	-	-	-	-	-	-	-
Elymus repens	-	-	-	-	-	-	-	-
Epilobium ciliatum	-	-	-	-	-	-	-	-
Euphrasia officinalis agg.	-	-	-	-	-	-	-	-
Festuca rubra	-	-	-	0.95	-	-	-	0.32
Galium aparine	-	-	0.11	-	-	-	0.04	-
Heracleum sphondylium	-	25.22	-	-	-	-	-	8.41
Hieracium pilosella	-	-	-	-	-	-	-	-
Holcus lanatus	218.19	157.72	171.76	177.00	297.12	286.48	229.02	207.07
Holcus mollis	-	-	-	-	181.23	170.92	60.41	56.97
Hordeum vulgare	-	-	-	-	-	-	-	-
Hypochoeris radicata	-	-	-	-	-	-	-	-
Juncus bufonius	-	-	-	-	-	-	-	-
Leucanthemum vulgare	-	-	-	-	-	-	-	-
Lolium perenne	21.60	-	2.83	-	3.28	9.85	9.24	3.28
Luzula campestris	-	-	-	-	-	-	-	-
Plantago lanceolata	-	-	0.35	-	1.40	-	0.58	-
Poa trivialis	6.62	5.87	2.47	2.52	14.65	4.46	7.91	4.28
Polygonum aviculare	-	-	-	-	-	-	-	-
Quercus robur	-	-	-	-	-	-	-	-
Ranunculus spp.	1.46	5.24	6.07	1.46	0.45	6.64	2.66	4.45
Rhinanthus minor	0.14	-	0.49	0.80	-	-	0.21	0.27
Rumex acetosa	55.96	34.24	26.38	18.48	-	-	27.45	17.58
Rumex crispus	-	-	-	-	-	-	-	-
Rumex obtusifolius	-	-	-	-	-	-	-	-
Senecio jacobaea	-	-	-	-	-	-	-	-
Solanum tuberosum	-	-	-	-	-	-	-	-
Sonchus asper	-	-	-	-	-	-	-	-
Taraxacum spp.	-	-	-	0.66	-	-	-	0.22
Trifolium dubium	-	-	-	-	-	-	-	-
Trifolium pratense	-	-	-	-	-	-	-	-
Trifolium repens	-	-	-	-	-	-	-	-
Tripleurospermum inodoratum	-	-	-	-	-	-	-	-
Trisetum flavescens	-	-	-	-	-	-	-	-
Veronica arvensis	-	-	-	-	-	-	-	-
Vicia sativa	-	-	-	-	-	-	-	-
Viola arvensis	-	-	-	-	-	-	-	-
Vulpia bromoides	-	-	-	-	-	-	-	-
Total	718.44	617.98	684.76	662.96	946.47	927.15	783.22	736.03

Table 6.6 Continued:

Treatment / Replicate / Species / Year	Control -N A 1988	Control -N A 1989	Control -N B 1988	Control -N B 1989	Control -N C 1988	Control -N C 1989	Control -N Mean 1988	Control -N Mean 1989
Agrostis capillaris	405.03	213.30	331.77	389.40	305.61	222.77	347.47	275.16
Agrostis gigantea	-	-	72.94	102.01	68.83	-	47.26	34.01
Anthoxanthum odoratum	-	0.15	-	0.57	-	-	-	0.24
Bromus mollis	-	0.17	0.65	1.84	-	6.24	0.22	2.75
Centaurea nigra	-	-	-	-	-	-	-	-
Cerastium fontanum	-	-	-	-	-	-	-	-
Cirsium arvense	-	-	-	-	-	-	-	-
Cynosurus cristatus	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	87.28	121.40	103.14	121.77	63.47	81.06
Daucus carota	-	-	-	-	-	-	-	-
Elymus repens	-	-	-	-	-	-	-	-
Epilobium ciliatum	-	-	-	-	-	-	-	-
Euphrasia officinalis agg.	-	-	-	-	-	-	-	-
Festuca rubra	-	-	-	-	-	-	-	-
Galium aparine	-	-	-	-	-	-	-	-
Heracleum sphondylium	-	-	-	-	-	-	-	-
Hieracium pilosella	-	-	-	-	-	-	-	-
Holcus lanatus	136.75	46.60	358.82	210.68	477.36	504.45	324.31	253.91
Holcus mollis	-	-	-	-	-	-	-	-
Hordeum vulgare	-	-	-	-	-	-	-	-
Hypochoeris radicata	-	-	0.45	-	-	-	0.15	-
Juncus bufonius	-	-	-	-	-	-	-	-
Leucanthemum vulgare	-	-	-	-	-	-	-	-
Lolium perenne	0.56	-	-	1.44	1.83	1.08	0.80	0.84
Luzula campestris	-	-	-	-	-	-	-	-
Plantago lanceolata	-	-	10.30	-	-	-	3.43	-
Poa trivialis	3.99	5.54	33.34	13.91	23.36	33.29	20.23	17.58
Polygonum aviculare	-	-	-	-	-	-	-	-
Quercus robur	0.33	-	-	-	-	-	0.11	-
Ranunculus spp.	27.70	21.90	21.90	2.55	8.76	-	10.09	10.22
Rhinanthus minor	0.51	14.90	3.40	-	-	-	1.30	4.97
Rumex acetosa	56.63	43.44	-	-	0.39	13.85	19.01	19.10
Rumex crispus	-	-	-	-	-	-	-	-
Rumex obtusifolius	-	-	-	-	-	-	-	-
Senecio jacobaea	-	-	-	-	-	-	-	-
Solanum tuberosum	-	-	-	-	-	-	-	-
Sonchus asper	-	-	-	-	-	-	-	-
Taraxacum spp.	0.08	-	0.07	-	-	-	0.05	-
Trifolium dubium	-	-	-	-	-	-	-	-
Trifolium pratense	-	-	-	-	-	-	-	-
Trifolium repens	-	-	-	-	-	-	-	-
Tripleurospermum inodoratum	-	-	-	-	-	-	-	-
Trisetum flavescens	-	-	-	-	-	-	-	-
Veronica arvensis	-	-	-	-	-	-	-	-
Vicia sativa	-	-	-	-	-	-	-	-
Viola arvensis	-	-	-	-	-	-	-	-
Vulpia bromoides	-	-	-	-	-	-	-	-
Total	631.58	345.99	901.55	850.00	980.51	903.44	837.88	699.81

Table 6.6 Continued:

Species / Treatment / Replicate / Year	Leaching +N A 1988	Leaching +N A 1989	Leaching +N B 1988	Leaching +N B 1989	Leaching +N C 1988	Leaching +N C 1989	Leaching +N Mean 1988	Leaching +N Mean 1989
Agrostis capillaris	-	1.10	0.06	2.79	0.65	9.54	0.24	4.48
Agrostis gigantea	32.96	3.33	15.79	-	75.93	-	41.56	1.11
Anthoxanthum odoratum	-	7.53	2.27	15.28	2.44	12.67	1.57	11.83
Bromus mollis	-	-	-	-	13.75	0.31	4.58	0.10
Centaurea nigra	-	-	-	-	-	-	-	-
Cerastium fontanum	0.11	0.13	1.18	0.07	0.53	0.18	0.61	0.13
Cirsium arvense	-	-	-	19.15	-	-	-	6.38
Cynosurus cristatus	1.8	24.80	0.42	15.00	1.85	23.97	1.36	21.25
Dactylis glomerata	-	-	-	-	-	-	-	-
Daucus carota	-	-	-	-	-	-	-	-
Elymus repens	-	-	2.68	-	-	0.79	0.89	0.26
Epilobium ciliatum	-	-	6.86	0.07	0.25	-	2.37	0.02
Euphrasia officinalis agg.	-	-	-	-	-	-	-	-
Festuca rubra	0.40	4.57	2.48	5.55	20.53	8.32	7.80	6.15
Galium aparine	-	-	-	-	-	-	-	-
Heracleum sphondylium	-	-	-	-	-	-	-	-
Hieracium pilosella	-	-	-	-	-	-	-	-
Holcus lanatus	419.29	163.36	175.25	187.31	257.82	175.93	284.12	175.53
Holcus mollis	-	-	-	1.32	-	10.27	-	3.86
Hordeum vulgare	-	-	-	-	-	-	-	-
Hypochoeris radicata	0.30	24.16	18.14	16.06	15.05	-	11.16	13.41
Juncus bufonius	-	-	-	-	-	-	-	-
Leucanthemum vulgare	192.86	143.13	189.09	269.66	134.32	239.51	172.09	217.43
Lolium perenne	-	-	-	-	-	-	-	-
Luzula campestris	-	-	-	-	-	-	-	-
Plantago lanceolata	40.61	192.55	54.41	204.48	58.92	159.90	51.32	185.64
Poa trivialis	0.13	-	3.38	-	2.11	-	1.87	-
Polygonum aviculare	-	-	-	-	-	-	-	-
Quercus robur	-	-	-	-	-	-	-	-
Ranunculus spp.	2.35	0.20	0.97	1.94	3.12	0.12	2.14	0.75
Rhinanthus minor	3.25	0.70	6.41	0.17	3.96	0.03	4.54	0.30
Rumex acetosa	8.53	19.45	0.80	1.19	-	37.18	3.11	19.28
Rumex crispus	-	-	-	-	-	-	-	-
Rumex obtusifolius	-	-	-	-	-	-	-	-
Senecio jacobaea	-	-	-	-	-	-	-	-
Solanum tuberosum	-	-	-	-	-	-	-	-
Sonchus asper	-	-	-	-	-	-	-	-
Taraxacum spp.	-	-	-	-	-	-	-	-
Trifolium dubium	-	0.13	-	-	-	-	-	0.05
Trifolium pratense	0.28	1.50	-	0.75	-	1.52	0.10	1.26
Trifolium repens	0.17	0.10	0.09	-	0.02	-	0.10	0.03
Tripleurospermum inodoratum	18.64	-	0.37	-	-	-	6.34	-
Trisetum flavescens	-	1.97	-	-	1.81	1.22	0.60	1.06
Veronica arvensis	-	-	0.10	-	-	-	0.04	-
Vicia sativa	-	-	-	0.64	-	-	-	-
Viola arvensis	-	-	-	-	-	-	-	-
Vulpia bromoides	-	-	-	-	-	-	-	-
Total	721.68	588.71	480.74	741.40	593.04	681.44	598.49	670.52

Table 6.6 Continued:

Treatment / Replicate / Species / Year	Leaching -N A 1988	1989	Leaching -N B 1988	1989	Leaching -N C 1988	1989	Leaching -N Mean 1988	1989
Agrostis capillaris	3.20	4.52	-	0.40	-	4.56	1.07	3.16
Agrostis gigantea	1.71	-	70.63	5.60	100.03	11.07	57.46	5.56
Anthoxanthum odoratum	1.49	12.66	3.60	10.60	5.26	25.75	3.45	16.34
Bromus mollis	-	-	-	-	-	-	-	-
Centaurea nigra	-	-	-	-	0.11	-	0.04	-
Cerastium fontanum	0.60	0.03	2.76	0.19	1.39	0.34	1.59	0.19
Cirsium arvense	2.10	-	-	-	-	-	0.70	-
Cynosurus cristatus	2.65	27.24	4.28	6.47	0.45	13.89	2.46	15.87
Dactylis glomerata	-	-	-	3.37	-	-	-	1.12
Daucus carota	-	12.89	-	-	-	-	-	4.30
Elymus repens	-	-	-	-	-	-	-	-
Epilobium ciliatum	0.72	-	-	-	0.48	-	0.40	-
Euphrasia officinalis agg.	-	-	-	-	-	-	-	-
Festuca rubra	0.46	2.34	3.70	4.60	5.41	7.91	3.19	4.95
Galium aparine	-	-	-	-	-	-	-	-
Heracleum sphondylium	-	-	-	-	-	-	-	-
Hieracium pilosella	-	-	-	-	-	-	-	-
Holcus lanatus	347.54	244.70	167.35	166.22	184.69	157.99	233.19	189.64
Holcus mollis	-	-	-	-	-	-	-	-
Hordeum vulgare	-	-	-	-	-	-	-	-
Hypochoeris radicata	0.46	14.49	2.38	14.62	23.03	73.90	8.63	34.34
Juncus bufonius	-	-	-	-	-	-	-	-
Leucanthemum vulgare	51.88	109.84	342.06	303.58	126.29	154.92	173.41	189.45
Lolium perenne	-	-	-	-	-	-	-	-
Luzula campestris	-	-	-	0.03	-	-	-	0.01
Plantago lanceolata	16.04	110.35	86.61	131.26	62.75	127.38	55.13	123.00
Poa trivialis	0.45	-	0.01	-	1.56	0.24	0.67	0.08
Polygonum aviculare	-	-	-	-	8.16	-	2.72	-
Quercus robur	-	-	-	-	-	-	-	-
Ranunculus spp.	-	4.55	3.42	2.42	2.10	1.95	1.84	2.97
Rhinanthus minor	5.42	4.07	15.41	-	11.33	0.37	10.72	1.48
Rumex acetosa	0.10	0.16	-	-	-	-	0.04	0.05
Rumex crispus	27.81	-	-	11.21	-	-	9.27	3.74
Rumex obtusifolius	-	-	-	-	-	-	-	-
Senecio jacobaea	-	-	-	-	-	-	-	-
Solanum tuberosum	-	-	-	-	-	-	-	-
Sonchus asper	-	-	-	-	-	-	-	-
Taraxacum spp.	-	-	-	-	-	-	-	-
Trifolium dubium	-	-	-	-	-	-	-	-
Trifolium pratense	-	0.35	0.58	-	0.09	2.95	0.22	1.10
Trifolium repens	0.04	0.07	-	-	-	-	0.01	0.02
Tripleurospermum inodoratum	42.84	-	3.29	-	-	0.06	15.38	0.02
Trisetum flavescens	-	0.03	0.16	7.73	0.21	7.72	0.12	5.16
Veronica arvensis	-	-	-	-	-	-	-	-
Vicia sativa	-	-	-	-	-	-	-	-
Viola arvensis	-	-	-	-	-	-	-	-
Vulpia bromoides	-	-	-	-	-	-	-	-
Total	505.49	548.28	706.22	668.29	533.33	590.98	581.68	602.52

Table 6.6 Continued:

Species / Treatment / Replicate / Year	Potatoes +N A 1988	Potatoes +N A 1989	Potatoes +N B 1988	Potatoes +N B 1989	Potatoes +N C 1988	Potatoes +N C 1989	Potatoes +N Mean 1988	Potatoes +N Mean 1989
Agrostis capillaris	0.10	3.14	0.90	7.65	3.53	43.99	1.51	18.26
Agrostis gigantea	23.12	-	178.66	10.58	150.06	11.82	117.28	7.47
Anthoxanthum odoratum	3.81	16.16	3.79	20.16	17.56	32.09	8.39	22.80
Bromus mollis	-	-	-	-	-	4.37	-	1.46
Centaurea nigra	0.36	0.18	-	-	-	0.15	0.12	0.11
Cerastium fontanum	1.07	0.21	3.41	0.66	1.92	0.36	2.13	0.41
Cirsium arvense	-	-	-	-	-	-	-	-
Cynosurus cristatus	4.85	19.33	2.64	27.36	0.11	1.98	2.53	16.23
Dactylis glomerata	-	-	-	-	-	0.74	-	0.25
Daucus carota	-	-	-	-	-	-	-	-
Elymus repens	-	-	-	-	-	-	-	-
Epilobium ciliatum	0.02	-	-	-	0.28	-	0.10	-
Euphrasia officinalis agg.	-	-	0.05	-	0.02	-	0.02	-
Festuca rubra	7.33	10.84	5.25	7.83	10.13	21.08	7.57	13.25
Galium aparine	-	-	-	-	-	-	-	-
Heracleum sphondylium	-	-	-	-	-	-	-	-
Hieracium pilosella	-	-	-	-	-	-	-	-
Holcus lanatus	230.28	224.69	215.67	124.52	121.59	33.82	189.18	127.68
Holcus mollis	38.59	51.79	-	-	-	-	12.86	17.27
Hordeum vulgare	-	-	-	-	-	-	-	-
Hypochoeris radicata	24.86	45.45	9.92	30.48	39.88	35.57	24.89	37.17
Juncus bufonius	0.02	-	0.02	-	0.12	-	0.05	-
Leucanthemum vulgare	256.75	221.67	68.31	152.94	172.70	98.93	165.92	157.85
Lolium perenne	-	-	-	-	-	-	-	-
Luzula campestris	-	0.15	-	-	-	0.08	-	0.08
Plantago lanceolata	102.01	218.50	37.22	100.90	4.37	12.71	47.87	110.70
Poa trivialis	-	-	1.09	-	0.38	-	0.49	-
Polygonum aviculare	-	-	-	-	-	-	-	-
Quercus robur	-	-	-	-	-	-	-	-
Ranunculus spp.	2.79	1.87	0.64	0.19	10.67	4.02	4.56	2.03
Rhinanthus minor	14.24	0.06	16.03	1.94	32.16	17.98	20.81	6.66
Rumex acetosa	9.39	2.72	-	0.59	8.37	-	5.92	1.10
Rumex crispus	-	-	-	-	2.59	-	0.87	-
Rumex obtusifolius	-	-	-	-	-	-	-	-
Senecio jacobaea	-	-	-	-	-	-	-	-
Solanum tuberosum	-	-	-	-	-	-	-	-
Sonchus asper	-	-	-	-	-	-	-	-
Taraxacum spp.	-	-	-	-	-	-	-	-
Trifolium dubium	-	-	0.08	-	-	-	0.03	-
Trifolium pratense	0.02	3.81	-	-	-	5.80	0.01	3.20
Trifolium repens	-	-	-	0.34	-	4.22	-	1.52
Tripleurospermum inodoratum	23.76	-	-	-	10.84	-	11.53	-
Trisetum flavescens	-	0.39	0.85	0.31	0.07	-	0.31	0.24
Veronica arvensis	-	-	-	-	-	-	-	-
Vicia sativa	-	-	-	-	-	-	-	-
Viola arvensis	-	-	-	-	-	-	-	-
Vulpia bromoides	-	-	-	-	-	-	-	-
Total	743.33	820.95	544.49	486.44	586.92	329.68	624.92	545.69

Table 6.6 Continued:

Species	Treatment Replicate Year	Potatoes -N A 1988	 1989	Potatoes -N B 1988	 1989	Potatoes -N C 1988	 1989	Potatoes -N Mean 1988	 1989
Agrostis capillaris		2.71	28.36	0.24	0.77	3.41	6.92	2.12	12.02
Agrostis gigantea		111.01	3.58	13.34	8.10	35.22	1.66	53.19	4.45
Anthoxanthum odoratum		16.07	14.43	20.92	28.12	5.01	39.04	14.00	27.19
Bromus mollis		-	-	-	-	-	0.24	-	0.08
Centaurea nigra		-	-	0.64	22.41	-	9.63	0.21	10.68
Cerastium fontanum		-	0.02	-	-	0.18	0.18	0.06	0.07
Cirsium arvense		-	-	-	-	-	-	-	-
Cynosurus cristatus		7.00	12.34	0.14	6.04	-	5.26	2.38	7.84
Dactylis glomerata		-	2.43	1.02	0.04	1.30	-	0.77	0.82
Daucus carota		-	-	-	-	-	-	-	-
Elymus repens		-	-	-	-	-	-	-	-
Epilobium ciliatum		0.04	-	-	-	-	-	0.01	-
Euphrasia officinalis agg.		0.17	-	-	-	-	-	0.06	-
Festuca rubra		1.44	5.54	6.99	6.66	10.57	14.27	6.33	8.83
Galium aparine		-	-	-	-	-	-	-	-
Heracleum sphondylium		-	-	-	-	-	-	-	-
Hieracium pilosella		-	-	-	-	-	-	-	-
Holcus lanatus		148.40	45.74	43.61	68.85	6.27	26.74	66.09	47.11
Holcus mollis		-	-	-	-	-	-	-	-
Hordeum vulgare		-	-	-	-	-	-	-	-
Hypochoeris radicata		8.42	43.69	134.87	97.30	73.59	77.10	72.29	72.69
Juncus bufonius		-	-	-	-	-	-	-	-
Leucanthemum vulgare		82.11	77.92	82.97	230.00	8.81	168.11	57.96	158.68
Lolium perenne		-	-	-	-	-	-	-	-
Luzula campestris		-	-	-	-	-	-	-	-
Plantago lanceolata		24.97	65.85	35.00	51.63	37.60	79.58	32.52	65.89
Poa trivialis		2.06	-	0.90	-	2.67	-	1.88	-
Polygonum aviculare		-	-	0.02	-	0.40	-	0.14	-
Quercus robur		-	-	-	-	-	-	-	-
Ranunculus spp.		2.40	2.57	0.78	1.47	1.14	5.50	1.44	3.18
Rhinanthus minor		24.51	11.36	23.81	0.04	37.99	2.90	28.77	4.77
Rumex acetosa		-	0.10	-	-	0.16	0.18	0.05	0.09
Rumex crispus		-	-	-	-	-	-	-	-
Rumex obtusifolius		-	-	-	-	-	-	-	-
Senecio jacobaea		-	1.42	-	-	-	-	-	0.47
Solanum tuberosum		-	-	-	-	1.32	-	0.44	-
Sonchus asper		-	-	-	-	-	-	-	-
Taraxacum spp.		-	-	-	-	-	-	-	-
Trifolium dubium		-	-	-	-	-	0.50	-	0.17
Trifolium pratense		-	-	0.69	4.12	-	6.33	0.23	3.48
Trifolium repens		0.33	5.28	-	-	-	5.70	0.11	3.66
Tripleurospermum inodoratum		28.78	-	26.42	-	-	0.30	18.40	0.10
Trisetum flavescens		0.19	0.33	-	-	-	0.24	0.07	0.19
Veronica arvensis		-	-	-	-	-	-	-	-
Vicia sativa		-	-	-	-	-	-	-	-
Viola arvensis		-	-	-	-	-	-	-	-
Vulpia bromoides		-	-	-	-	-	-	-	-
Total		460.61	320.83	392.34	525.54	225.60	450.34	359.52	432.24

Table 6.6 Continued:

Treatment	Barley +N		Barley +N		Barley +N		Barley +N	
Replicate	A		B		C		Mean	
Species Year	1988	1989	1988	1989	1988	1989	1988	1989
Agrostis capillaris	11.02	76.41	0.87	26.87	0.32	0.71	4.07	34.66
Agrostis gigantea	131.98	18.00	19.35	-	315.24	3.90	155.53	7.30
Anthoxanthum odoratum	4.63	26.28	3.33	34.47	1.94	13.19	3.30	24.65
Bromus mollis	4.33	0.53	-	-	-	0.96	1.44	0.50
Centaurea nigra	0.04	0.83	-	-	-	-	0.01	0.28
Cerastium fontanum	0.05	0.03	0.26	0.34	0.10	0.14	0.14	0.17
Cirsium arvense	-	-	-	-	-	-	-	-
Cynosurus cristatus	0.09	0.83	0.48	1.40	0.85	8.54	0.47	3.59
Dactylis glomerata	0.42	-	-	-	-	0.07	0.14	0.02
Daucus carota	-	-	-	-	-	-	-	-
Elymus repens	-	-	-	-	-	-	-	-
Epilobium ciliatum	-	-	-	-	0.53	-	0.18	-
Euphrasia officinalis agg.	-	-	-	-	-	-	-	-
Festuca rubra	11.80	19.33	0.36	8.45	0.79	5.18	4.31	10.99
Galium aparine	-	-	-	-	-	-	-	-
Heracleum sphondylium	-	-	-	-	-	-	-	-
Hieracium pilosella	-	0.03	-	-	-	-	-	0.01
Holcus lanatus	106.24	68.77	262.32	107.91	56.70	64.34	141.75	80.34
Holcus mollis	-	-	-	19.91	-	-	-	6.64
Hordeum vulgare	-	-	2.11	-	-	-	0.70	-
Hypochoeris radicata	50.56	103.74	10.71	17.11	35.86	52.93	32.38	57.93
Juncus bufonius	-	-	-	-	0.02	-	0.01	-
Leucanthemum vulgare	100.19	95.24	100.26	117.63	37.55	196.07	79.33	136.32
Lolium perenne	-	-	-	-	-	-	-	-
Luzula campestris	-	-	-	-	-	-	-	-
Plantago lanceolata	8.43	23.44	61.57	202.02	53.68	140.60	41.23	122.02
Poa trivialis	1.86	-	0.32	-	2.57	-	1.58	-
Polygonum aviculare	-	-	-	-	-	-	-	-
Quercus robur	-	-	-	-	-	-	-	-
Ranunculus spp.	5.45	10.22	4.22	6.88	4.16	1.95	4.61	6.35
Rhinanthus minor	25.17	11.11	14.57	0.77	31.03	3.44	23.59	5.11
Rumex acetosa	0.09	1.11	18.45	13.42	0.46	1.63	6.33	5.39
Rumex crispus	-	-	-	-	-	-	-	-
Rumex obtusifolius	-	-	-	-	-	-	-	-
Senecio jacobaea	-	-	-	-	-	-	-	-
Solanum tuberosum	-	-	-	-	-	-	-	-
Sonchus asper	-	-	-	-	-	-	-	-
Taraxacum spp.	-	-	-	-	-	-	-	-
Trifolium dubium	-	-	-	-	-	-	-	-
Trifolium pratense	-	-	-	5.56	-	2.73	-	2.76
Trifolium repens	0.25	7.89	0.08	5.14	0.07	0.53	0.13	4.52
Tripleurospermum inodoratum	-	-	-	-	6.86	-	2.29	-
Trisetum flavescens	-	-	-	0.81	-	0.36	-	0.39
Veronica arvensis	-	-	-	-	-	-	-	-
Vicia sativa	-	-	-	-	-	-	-	-
Viola arvensis	-	-	-	-	-	-	-	-
Vulpia bromoides	-	-	-	-	0.59	-	0.20	-
Total	462.57	463.78	499.25	568.67	549.30	497.26	503.71	509.90

Table 6.6 Continued:

Species	Treatment Replicate Year	Barley -N A 1988	 1989	Barley -N B 1988	 1989	Barley -N C 1988	 1989	Barley -N Mean 1988	 1989
Agrostis capillaris		1.09	95.94	0.19	3.17	0.35	9.92	0.54	36.34
Agrostis gigantea		8.26	-	73.25	0.43	63.78	-	48.43	0.14
Anthoxanthum odoratum		2.44	31.89	7.84	11.92	5.82	37.88	5.37	27.23
Bromus mollis		-	0.24	-	0.03	0.74	0.03	0.25	0.10
Centaurea nigra		-	-	-	-	-	-	-	-
Cerastium fontanum		0.20	0.34	0.38	-	0.18	0.47	0.25	0.27
Cirsium arvense		23.62	15.36	-	-	-	-	7.87	5.12
Cynosurus cristatus		0.53	7.42	-	0.86	0.33	3.34	0.29	3.88
Dactylis glomerata		-	-	-	-	-	-	-	-
Daucus carota		-	-	-	-	-	-	-	-
Elymus repens		-	-	-	-	-	-	-	-
Epilobium ciliatum		0.25	-	-	-	0.07	-	0.11	-
Euphrasia officinalis agg.		-	-	-	-	-	-	-	-
Festuca rubra		10.75	13.54	2.43	6.02	7.32	19.22	6.83	12.93
Galium aparine		-	-	-	-	-	-	-	-
Heracleum sphondylium		-	-	-	-	-	-	-	-
Hieracium pilosella		-	-	-	-	-	-	-	-
Holcus lanatus		105.43	77.72	16.63	6.58	22.18	39.44	48.08	41.25
Holcus mollis		-	6.18	-	-	-	-	-	2.06
Hordeum vulgare		-	-	-	-	-	-	-	-
Hypochoeris radicata		24.95	30.34	105.50	40.33	96.13	109.29	75.53	59.99
Juncus bufonius		-	-	-	-	-	-	-	-
Leucanthemum vulgare		29.93	102.45	66.27	136.24	73.34	283.73	56.51	174.14
Lolium perenne		0.65	0.07	-	-	-	-	0.22	0.02
Luzula campestris		-	-	-	-	-	-	-	-
Plantago lanceolata		36.90	162.26	7.71	33.16	21.36	53.88	21.99	83.10
Poa trivialis		4.84	-	0.53	-	2.37	-	2.58	-
Polygonum aviculare		-	-	-	-	0.01	-	<0.01	-
Quercus robur		-	-	-	-	-	-	-	-
Ranunculus spp.		1.20	4.91	1.04	1.45	1.78	5.12	1.34	3.83
Rhinanthus minor		30.15	7.33	37.99	9.94	40.66	-	36.26	5.75
Rumex acetosa		3.22	1.95	14.23	17.21	-	-	5.82	6.39
Rumex crispus		12.37	-	-	-	-	-	4.12	-
Rumex obtusifolius		-	-	-	-	-	-	-	-
Senecio jacobaea		-	-	-	-	-	-	-	-
Solanum tuberosum		-	-	-	-	-	-	-	-
Sonchus asper		0.76	-	-	-	-	-	0.25	-
Taraxacum spp.		1.00	-	0.41	-	-	-	0.47	-
Trifolium dubium		-	-	-	-	-	-	-	-
Trifolium pratense		-	1.68	0.76	0.81	-	2.00	0.25	1.50
Trifolium repens		1.23	0.37	0.36	1.61	0.10	-	0.56	0.66
Tripleurospermum inodoratum		2.62	-	-	-	31.79	-	11.47	-
Trisetum flavescens		-	-	-	-	-	-	-	-
Veronica arvensis		-	-	-	-	-	-	-	-
Vicia sativa		-	-	-	-	-	-	-	-
Viola arvensis		-	-	-	-	-	-	-	-
Vulpia bromoides		-	-	-	-	-	-	-	-
Total		302.35	559.95	335.49	269.74	368.30	564.32	335.38	464.67

Table 6.6 Continued:

Treatment / Replicate / Species / Year	Maize +N A 1988	1989	Maize +N B 1988	1989	Maize +N C 1988	1989	Maize +N Mean 1988	1989
Agrostis capillaris	1.79	15.64	-	15.79	0.36	31.85	0.72	21.09
Agrostis gigantea	292.38	-	21.86	-	139.55	-	151.26	-
Anthoxanthum odoratum	1.57	15.94	15.62	52.69	3.14	29.96	6.78	32.86
Bromus mollis	17.91	4.01	8.18	9.94	32.14	0.76	19.41	4.90
Centaurea nigra	-	-	-	-	-	-	-	-
Cerastium fontanum	0.13	-	0.21	0.58	1.34	-	0.56	0.19
Cirsium arvense	-	-	-	-	-	-	-	-
Cynosurus cristatus	0.65	30.50	0.93	8.25	-	-	0.53	12.92
Dactylis glomerata	-	-	-	-	1.53	-	0.51	-
Daucus carota	-	-	-	-	-	-	-	-
Elymus repens	-	-	126.26	71.40	-	-	42.09	23.80
Epilobium ciliatum	-	-	-	-	0.46	-	0.16	-
Euphrasia officinalis agg.	-	-	-	-	-	-	-	-
Festuca rubra	1.64	7.39	10.86	21.25	18.63	18.93	10.38	15.86
Galium aparine	-	-	-	-	-	-	-	-
Heracleum sphondylium	-	-	-	-	-	-	-	-
Hieracium pilosella	-	-	-	-	-	-	-	-
Holcus lanatus	182.50	105.92	127.51	184.94	625.52	603.91	311.83	298.26
Holcus mollis	-	-	-	-	-	-	-	-
Hordeum vulgare	-	-	-	-	-	-	-	-
Hypochoeris radicata	2.55	15.23	0.10	5.72	23.62	36.45	8.75	19.14
Juncus bufonius	-	-	0.02	-	-	-	0.01	-
Leucanthemum vulgare	47.72	119.74	61.61	79.74	11.78	47.52	40.37	82.33
Lolium perenne	-	-	-	-	25.49	23.95	8.50	7.98
Luzula campestris	-	-	-	-	-	-	-	-
Plantago lanceolata	33.75	104.10	21.20	89.19	9.38	68.64	21.44	87.31
Poa trivialis	1.97	-	3.51	-	1.18	-	2.22	-
Polygonum aviculare	-	-	-	-	-	-	-	-
Quercus robur	-	-	-	-	-	-	-	-
Ranunculus spp.	6.26	1.64	1.12	0.62	0.93	0.49	2.77	0.92
Rhinanthus minor	13.26	14.97	6.66	14.73	6.88	1.66	8.93	10.45
Rumex acetosa	2.16	16.98	-	-	-	-	0.72	5.66
Rumex crispus	-	-	-	-	-	-	-	-
Rumex obtusifolius	15.99	28.72	-	-	-	-	5.33	9.57
Senecio jacobaea	-	-	-	-	-	-	-	-
Solanum tuberosum	-	-	-	-	-	-	-	-
Sonchus asper	-	-	-	-	-	-	-	-
Taraxacum spp.	-	-	-	-	-	-	-	-
Trifolium dubium	-	-	-	-	-	-	-	-
Trifolium pratense	-	-	-	0.80	0.09	-	0.03	0.27
Trifolium repens	-	-	-	0.58	-	-	-	0.19
Tripleurospermum inodoratum	9.62	-	-	-	-	-	3.21	-
Trisetum flavescens	0.24	-	-	-	-	-	0.08	-
Veronica arvensis	-	-	-	-	-	-	-	-
Vicia sativa	-	-	-	-	-	-	-	-
Viola arvensis	-	-	-	-	-	-	-	-
Vulpia bromoides	-	-	-	-	-	-	-	-
Total	632.07	480.76	405.63	556.20	901.99	864.10	646.56	633.69

Table 6.6 Continued:

Species	Treatment: Maize -N, Replicate: A, 1988	A, 1989	Maize -N B, 1988	B, 1989	Maize -N C, 1988	C, 1989	Maize -N Mean, 1988	Mean, 1989
Agrostis capillaris	1.27	2.67	4.31	3.25	1.72	15.61	2.43	7.18
Agrostis gigantea	257.87	7.14	302.62	15.51	151.25	4.44	237.25	9.03
Anthoxanthum odoratum	4.36	16.89	3.18	28.86	6.69	40.59	4.74	28.71
Bromus mollis	0.64	0.06	10.00	1.68	0.91	0.62	3.85	0.78
Centaurea nigra	-	-	-	-	-	-	-	-
Cerastium fontanum	-	-	0.97	-	-	-	0.33	-
Cirsium arvense	-	-	-	-	-	-	-	-
Cynosurus cristatus	0.72	18.18	0.28	47.46	0.03	1.58	0.34	22.41
Dactylis glomerata	-	-	-	-	0.02	0.62	0.01	0.21
Daucus carota	-	-	-	-	-	-	-	-
Elymus repens	-	-	-	-	0.67	-	0.22	-
Epilobium ciliatum	0.26	-	0.62	-	-	-	0.29	-
Euphrasia officinalis agg.	-	-	-	-	-	-	-	-
Festuca rubra	5.48	3.73	1.86	5.73	9.82	20.37	5.72	9.94
Galium aparine	-	-	-	-	-	-	-	-
Heracleum sphondylium	-	-	-	-	-	-	-	-
Hieracium pilosella	-	-	-	-	-	-	-	-
Holcus lanatus	154.46	37.87	144.72	124.68	59.96	41.15	119.71	67.90
Holcus mollis	-	-	-	-	-	-	-	-
Hordeum vulgare	-	-	-	-	-	-	-	-
Hypochoeris radicata	3.35	6.11	4.98	4.95	114.36	67.77	40.89	26.28
Juncus bufonius	-	-	-	-	-	-	-	-
Leucanthemum vulgare	49.71	47.15	36.91	79.99	75.94	227.61	54.19	118.25
Lolium perenne	-	-	-	-	1.08	7.45	0.36	2.49
Luzula campestris	-	-	-	-	-	0.09	-	0.03
Plantago lanceolata	30.99	73.41	43.26	88.53	20.81	23.79	31.69	61.91
Poa trivialis	6.31	-	2.75	0.07	3.46	-	4.17	0.03
Polygonum aviculare	0.72	-	-	-	-	-	0.24	-
Quercus robur	-	-	-	-	-	-	-	-
Ranunculus spp.	8.70	2.09	7.26	3.67	2.92	5.29	6.29	3.68
Rhinanthus minor	27.29	13.93	7.46	6.48	27.97	1.20	20.91	7.20
Rumex acetosa	1.60	4.44	0.09	0.15	0.02	-	0.57	1.53
Rumex crispus	15.31	7.93	-	-	-	-	5.10	2.65
Rumex obtusifolius	-	-	-	-	-	-	-	-
Senecio jacobaea	-	-	-	-	-	-	-	-
Solanum tuberosum	-	-	-	-	-	-	-	-
Sonchus asper	-	-	-	-	-	-	-	-
Taraxacum spp.	-	0.71	-	-	0.98	-	0.33	0.24
Trifolium dubium	5.02	-	-	-	-	-	1.67	-
Trifolium pratense	-	1.12	-	-	0.37	1.90	0.12	1.01
Trifolium repens	0.09	1.73	0.05	-	-	0.12	0.05	0.62
Tripleurospermum inodoratum	-	-	-	-	8.85	-	2.95	-
Trisetum flavescens	0.22	0.12	-	-	-	-	0.07	0.04
Veronica arvensis	-	-	-	-	-	-	-	-
Vicia sativa	-	-	-	-	-	-	-	-
Viola arvensis	-	-	-	-	-	-	-	-
Vulpia bromoides	-	-	-	-	-	-	-	-
Total	574.35	245.05	571.31	411.00	487.79	460.18	544.48	372.08

Table 6.7: Nested Means for Stand Ordination Scores Produced by DECORANA for the Full Standing Crop Data Set from the Cropping Experiment at Compton Agricultural Unit, Wolverhampton.

YEAR	TREATMENT	±N	REPLICATE ORD SCORE			MEAN 3	SE	MEAN 2	SE	MEAN 1	SE
			A	B	C						
1988	CONTROL	+N	259	272	257	262.67	± 4.70	250.33	± 9.13	99.60	±15.06
		-N	269	225	220	238.00	±15.57				
	LEACHING	+N	96	55	78	76.33	±11.87	74.00	±11.67		
		-N	115	36	64	71.67	±23.13				
	POTATO	+N	63	83	51	65.67	± 9.33	46.50	±13.20		
		-N	68	4	10	27.33	±20.41				
	BARLEY	+N	59	95	51	68.33	±13.53	49.83	±13.15		
		-N	68	16	10	31.33	±18.42				
	MAIZE	+N	81	60	132	91.00	±21.38	77.33	±13.38		
		-N	79	80	32	63.67	±15.84				
1989	CONTROL	+N	272	266	259	265.67	± 3.76	253.83	± 7.67	85.53	±16.41
		-N	263	241	222	242.00	±11.85				
	LEACHING	+N	46	36	56	46.00	± 5.77	46.50	± 6.17		
		-N	72	33	36	47.00	±12.53				
	POTATO	+N	56	39	55	50.00	± 5.51	32.83	±10.40		
		-N	45	2	0	15.67	±14.68				
	BARLEY	+N	70	57	11	46.00	±17.90	37.17	±14.11		
		-N	77	8	0	28.33	±24.44				
	MAIZE	+N	51	63	129	81.00	±24.25	57.33	±15.78		
		-N	33	51	17	33.67	± 9.82				

Table 6.8: Ranking of Treatments According to the Relative Mean Stand Ordination Scores Produced by DECORANA
(Based on Scores Presented in Mean Column 2 of Table 6.7).

Rank	Mean Score	Treatment	Year
1	46.50	Potatoes	1988
2	49.83	Barley	1988
3	74.00	Leaching	1988
4	77.33	Maize	1988
5	250.33	Control	1988

Rank	Mean Score	Treatment	Year
1	32.83	Potatoes	1989
2	37.17	Barley	1989
3	46.50	Leaching	1989
4	57.33	Maize	1989
5	253.83	Control	1989

Table 6.9: Species Ordination Produced by DECORANA for the Full Standing Crop Data Set for the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988 & 1989)

Species in bold were present in more than one plot.

AXIS 1	
SPECIES	SCORE
Heracleum sphondylium	366
Agrostis capillaris	317
Dactylis glomerata	293
Holcus mollis	276
Poa trivialis	256
Rumex acetosa	239
Lolium perenne	223
Ranunculus spp.	184
Holcus lanatus	163
Taraxacum sp.	129
Bromus mollis	91
Hordeum vulgare	86
Agrostis gigantea	62
Rumex crispus	48
Daucus carota	41
Cirsium arvense	30
Epilobium ciliatum	29
Sonchus asper	29
Rumex obtusifolius	17
Cerastium fontanum	16
Polygonum aviculare	15
Trifolium dubium	11
Elymus repens	10
Rhinanthus minor	10
Tripleurospermum inodoratum	9
Senecio jacobea	7
Festuca rubra	7
Trifolium repens	1
Anthoxanthum odoratum	0
Plantago lanceolata	-1
Cynosurus cristatus	-8
Leucanthemum vulgare	-18
Trisetum flavescens	-26
Vulpia bromoides	-32
Trifolium pratense	-36
Hypochoeris radicata	-43
Vicia sativa	-48
Solanum tuberosum	-107
Centaurea nigra	-119

Table 6.10a: Standing Crop of *Agrostis capillaris* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Nitrogen treatments not shown.

Treatment	Standing Crop (g/m^2)							
	Replicates						Mean	S.E.
	A	B	C	D	E	F		
Control	411.49	468.55	427.50	405.03	331.77	305.61	391.66	± 25.01
Leaching	-	0.06	0.65	3.20	-	-	0.65	± 0.52
Potatoes	0.10	0.90	3.53	2.71	0.24	3.41	1.82	± 0.65
Barley	11.02	0.87	0.32	1.09	0.19	0.35	2.31	± 1.75
Maize	1.79	-	0.36	1.27	4.31	1.72	1.58	± 0.62

Table 6.10b: Standing Crop of *Agrostis capillaris* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Nitrogen treatments not shown.

Treatment	Standing Crop (g/m^2)							
	Replicates						Mean	S.E.
	A	B	C	D	E	F		
Control	386.72	445.97	441.62	213.29	389.40	222.77	349.96	± 42.97
Leaching	1.10	2.79	9.54	4.52	0.40	4.56	3.82	± 1.34
Potatoes	3.14	7.65	43.99	28.36	0.77	6.92	15.14	± 7.03
Barley	76.41	26.87	0.71	95.94	3.17	9.92	35.50	± 16.64
Maize	15.64	15.79	31.85	2.67	3.25	15.61	14.14	± 4.36

Table 6.11: Ranking of Treatments According to the Relative Mean Stand Ordination Scores Produced by DECORANA.

(based on scores presented in mean column 2 of table 6.7).

Years 1988 & 1989 Combined.

Rank	Mean Score	Treatment	Year
1	32.83	Potatoes	1989
2	37.17	Barley	1989
3	46.50	Leaching	1989
3	46.50	Potatoes	1988
5	49.83	Barley	1988
6	57.33	Maize	1989
7	74.00	Leaching	1988
8	77.33	Maize	1988
9	250.33	Control	1988
10	253.83	Control	1989

Table 6.12: Ranking of Treatments According to the Relative Mean Stand Ordination Scores Produced by DECORANA
(based on score presented in mean column 3 of Table 6.7).

Rank	Mean Score	Treatment	±N	Year
1	27.33	Potatoes	-N	1988
2	31.33	Barley	-N	1988
3	63.67	Maize	-N	1988
4	65.67	Potatoes	+N	1988
5	68.33	Barley	+N	1988
6	71.67	Leaching	-N	1988
7	76.33	Leaching	+N	1988
8	91.00	Maize	+N	1988
9	238.00	Control	-N	1988
10	262.67	Control	+N	1988

Rank	Mean Score	Treatment	±N	Year
1	15.67	Potatoes	-N	1989
2	28.33	Barley	-N	1989
3	33.67	Maize	-N	1989
4	46.00	Barley	+N	1989
5	46.00	Leaching	+N	1989
6	47.00	Leaching	-N	1989
7	50.00	Potatoes	+N	1989
8	81.00	Maize	+N	1989
9	242.00	Control	-N	1989
10	265.67	Control	+N	1989

Table 6.13: Nested Means for Stand Ordination Scores Produced by DECORANA for the Full Standing Crop Data Set with the Control Plots Masked from the Cropping Experiment at Compton Agricultural Unit, Wolverhampton.

YEAR	TREATMENT	±N	REPLICATE ORD SCORE			MEAN 3	SE	MEAN 2	SE	MEAN 1	SE
			A	B	C						
1988	CONTROL	+N	-	-	-	-	-	-	-	119.63	± 7.25
		-N	-	-	-	-	-				
	LEACHING	+N	104	76	108	96.00	±10.07	99.33	± 8.95		
		-N	127	70	111	102.67	±16.97				
	POTATO	+N	59	148	122	109.67	±26.42	108.34	±13.30		
		-N	130	83	108	107.00	±13.58				
	BARLEY	+N	132	93	178	134.33	±24.57	121.67	±13.01		
		-N	91	116	120	109.00	± 9.07				
	MAIZE	+N	175	75	157	135.67	±30.78	149.17	±16.03		
		-N	172	178	138	162.67	±12.45				
1989	CONTROL	+N	-	-	-	-	-	-	-	36.71	± 3.96
		-N	-	-	-	-	-				
	LEACHING	+N	35	33	28	32.00	± 2.08	41.50	± 4.73		
		-N	59	45	49	51.00	± 4.16				
	POTATO	+N	28	42	33	34.33	± 4.10	30.17	± 3.26		
		-N	27	33	18	26.00	± 4.36				
	BARLEY	+N	43	9	29	27.00	± 9.87	23.67	± 6.57		
		-N	0	27	34	20.33	±10.37				
	MAIZE	+N	40	52	105	65.67	±19.97	51.50	±11.04		
		-N	32	43	37	37.33	± 3.18				

Table 6.14: Species Ordination Produced by DECORANA for the Full Standing Crop Data Set with Control Plots Masked for the Cropping Experiment at Compton Agricultural Unit, Wolverhampton.

Species in bold were present in more than one plot.

AXIS 1	
SPECIES	SCORE
Vulpia bromoides	329
Trifolium dubium	263
Agrostis gigantea	249
Poa trivialis	219
Bromus mollis	207
Polygonum aviculare	203
Rhinanthus minor	186
Solanum tuberosum	186
Tripleurospermum inodoratum	185
Cerastium fontanum	176
Epilobium ciliatum	175
Rumex crispus	174
Lolium perenne	169
Rumex obtusifolius	169
Taraxacum sp.	154
Ranunculus spp.	152
Holcus lanatus	144
Sonchus asper	126
Hordeum vulgare	110
Hypochoeris radicata	99
Festuca rubra	70
Dactylis glomerata	47
Leucanthemum vulgare	18
Elymus repens	17
Rumex acetosa	-19
Plantago lanceolata	-26
Anthoxanthum odoratum	-47
Trisetum flavescens	-68
Cirsium arvense	-72
Daucus carota	-72
Cynosurus cristatus	-101
Agrostis capillaris	-106
Holcus mollis	-175
Trifolium repens	-178
Trifolium pratense	-186
Senecio jacobea	-198
Vicia sativa	-209
Centaurea nigra	-217

Table 6.15: Mean Standing Crop for Meadow Species Recorded in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (values in g/m²).
Nitrogen treatments not shown.

Species	Control 1988	Control 1989	Leaching 1988	Leaching 1989	Potato 1988	Potato 1989	Barley 1988	Barley 1989	Maize 1988	Maize 1989
Agrostis capillaris	391.66	349.97	0.66	3.82	1.82	15.14	2.31	35.50	1.58	14.14
Agrostis gigantea	25.00	18.58	49.51	3.34	85.24	5.96	101.98	3.72	194.26	4.52
Anthoxanthum odoratum	0.49	1.44	2.51	14.09	11.20	25.00	4.34	25.94	5.76	30.79
Bromus mollis	0.11	0.75	2.29	0.05	-	0.77	0.85	0.30	11.63	2.84
Centaurea nigra	-	-	0.02	-	0.17	5.40	0.01	0.14	-	-
Cerastium fontanum	-	0.03	1.10	0.16	1.10	0.24	0.20	0.22	0.45	0.10
Cirsium arvense	-	-	0.35	3.19	-	-	3.89	2.56	-	-
Cynosurus cristatus	-	-	1.91	18.56	2.46	12.04	0.38	3.74	0.44	17.67
Dactylis glomerata	34.82	41.83	-	0.56	0.39	0.54	0.07	0.01	0.26	0.11
Daucus carota	-	-	-	2.15	-	-	-	-	-	-
Elymus repens	-	-	0.45	0.13	-	-	-	-	21.16	11.90
Epilobium ciliatum	-	-	1.39	0.01	0.06	-	0.15	-	0.23	-
Euphrasia officinalis agg.	-	-	-	-	0.04	-	-	-	-	-
Festuca rubra	-	0.16	5.50	5.55	6.95	11.04	5.57	11.96	8.16	12.90
Galium aparine	0.02	-	-	-	-	-	-	-	-	-
Heracleum sphondylium	-	4.21	-	-	-	-	-	-	-	-
Hieracium pilosella	-	-	-	-	-	-	-	0.01	-	-
Holcus lanatus	276.67	230.49	258.66	182.49	127.64	87.40	94.92	60.80	215.77	183.08
Holcus mollis	30.21	28.49	-	1.98	6.43	8.64	-	4.35	-	-
Hordeum vulgare	-	-	-	-	-	-	0.35	-	-	-
Hypochoeris radicata	0.08	-	9.91	23.88	48.59	54.93	53.96	58.96	24.82	22.71
Juncus bufonius	-	-	-	-	0.03	-	0.01	-	0.01	-
Leucanthemum vulgare	-	-	172.75	118.44	111.94	158.27	67.92	155.23	47.28	100.29
Lolium perenne	5.02	2.06	-	-	-	-	0.11	0.01	4.43	5.24
Luzula campestris	-	-	-	0.01	-	0.04	-	-	-	0.02
Plantago lanceolata	2.01	-	53.23	154.32	40.20	88.20	31.61	102.56	26.57	74.61
Poa trivialis	14.07	10.93	1.27	0.04	1.19	-	2.09	-	3.20	0.02
Polygonum aviculare	-	-	1.36	-	0.07	-	<0.01	-	0.12	-
Quercus robur	0.06	-	-	-	-	-	-	-	-	-
Ranunculus spp.	6.38	7.34	1.99	1.86	3.00	2.61	2.98	5.09	4.53	2.30
Rhinanthus minor	0.76	2.62	7.63	0.89	24.79	5.72	29.93	5.43	14.92	8.83
Rumex acetosa	23.23	18.34	1.58	9.67	2.99	0.60	6.08	5.89	0.65	3.60
Rumex crispus	-	-	4.64	1.74	0.44	-	2.06	-	2.55	1.33
Rumex obtusifolius	-	-	-	-	-	-	-	-	2.67	4.79
Senecio jacobaea	-	-	-	-	-	0.24	-	-	-	-
Solanum tuberosum	-	-	-	-	0.22	-	-	-	-	-
Sonchus asper	-	-	-	-	-	-	0.13	-	-	-
Taraxacum spp.	0.03	0.11	-	-	-	-	0.24	-	0.17	0.12
Trifolium dubium	-	-	-	0.03	0.02	0.09	-	-	0.84	-
Trifolium pratense	-	-	0.16	1.18	0.12	3.34	0.13	2.13	0.08	0.64
Trifolium repens	-	-	0.06	0.03	0.06	2.59	0.35	2.59	0.03	0.41
Tripleurospermum inodoratum	-	-	10.86	0.01	14.96	0.05	6.88	-	3.08	-
Trisetum flavescens	-	-	0.36	3.11	0.19	0.22	-	0.20	0.07	0.02
Veronica arvensis	-	-	0.02	-	-	-	-	-	-	-
Vicia sativa	-	-	-	0.11	-	-	-	-	-	-
Vulpia bromoides	-	-	-	-	-	-	0.10	-	-	-
Total	810.55	717.92	590.09	636.52	492.22	488.97	419.75	487.29	595.52	502.89

Table 6.16: Tables Showing Mean Values of Log Transformed Data and Significant Differences (+) Between Results from 1988 and 1989 for *Agrostis gigantea* Identified by Analysis of Variance ($P<0.05$, 5%LSD=0.55, n=6).
(control plots masked).

Treatment	1988	1989
Control	masked	masked
Leaching	1.49	0.42
Potatoes	1.76	0.70
Barley	1.76	0.35
Maize	2.18	0.48

TREATMENT	YEAR
LEACHING	+
POTATOES	+
BARLEY	+
MAIZE	+

Table 6.17a: Tables Showing Mean Values for Log Transformed Data and Significant Differences (+) Between Cropping Treatments for *Holcus lanatus* Identified by Analysis of Variance ($p<0.05$, 5%LSD=0.26, n=12).
(Control plots masked)

C = Control; L = Leaching; P = Potatoes; B = Barley; M = Maize

TREATMENT	Mean
CONTROL	Masked
LEACHING	2.32
POTATOES	1.87
BARLEY	1.74
MAIZE	2.14

L&P	L&B	L&M	P&B	P&M	B&M
+	+			+	+

Table 6.17b: Tables Showing Mean Values for Log Transformed Data and Significant Differences Between Nitrogen Treatments for *Holcus lanatus* Identified by Analysis of Variance ($p<0.05$, 5%LSD=0.37, n=6).
(Control plots masked)

Treatment	1988	1989
Control	masked	masked
Leaching	2.33	2.31
Potatoes	2.13	1.61
Barley	1.99	1.50
Maize	2.38	1.91

TREATMENT	±N
LEACHING	
POTATOES	+
BARLEY	+
MAIZE	+

Table 6.18: Tables Showing Mean Values for Log Transformed Data and Significant Differences (+) Between Cropping Treatments for *Hypochoeris radicata* Identified by Analysis of Variance ($P<0.05$, 5%LSD=0.53, n=6).
(Control plots masked)

C = Control; L = Leaching; P = Potatoes; B = Barley; M = Maize

Treatment	1988	1989
Control	masked	masked
Leaching	0.78	1.15
Potatoes	1.51	1.71
Barley	1.63	1.69
Maize	0.95	1.18

YEAR	L&P	L&B	L&M	P&B	P&M	B&M
1988	+	+			+	+
1989	+	+			+	

Table 6.19a: Tables Showing Mean Values for Log Transformed Data and Significant Differences (+) Between Cropping Treatments for *Rhinanthus minor* Identified by Analysis of Variance ($P<0.05$, 5%LSD=0.39, n=6).
(Control plots masked)

C = Control; L = Leaching; P = Potatoes; B = Barley; M = Maize

Treatment	1988	1989
Control	masked	masked
Leaching	0.89	0.19
Potatoes	1.39	0.58
Barley	1.47	0.66
Maize	1.13	0.87

YEAR	L&P	L&B	L&M	P&B	P&M	B&M
1988	+	+				
1989		+	+			

Table 6.19b: Significant Differences (+) Between Results from 1988 and 1989 for *Rhinanthus minor* Identified by Analysis of Variance.
Mean Values for Log Transformed Data Given in Table 6.19a.
(Control plots masked)

TREATMENT	YEAR
LEACHING	+
POTATOES	+
BARLEY	+
MAIZE	

FIGURES

Figure 6.1: Plan of the Experimental Area at Compton Agricultural Unit, Wolverhampton, Showing the Relative Positions of the Plots.
(not to scale).

E	I	F	A	A	C
E	D	A	F	B	E
G	H	H	B	F	J
D	J	C	D	G	J
B	I	G	I	H	C

15m

18m

KEY

A Leaching plus nitrogen
B Potatoes plus nitrogen
C Maize plus nitrogen
D Barley plus nitrogen
E Control plus nitrogen
F Leaching without nitrogen
G Potatoes without nitrogen
H Maize without nitrogen
I Barley without nitrogen
J Control without nitrogen

Figure 6.2a: Histogram Showing Mean Standing Crop for the Treatments in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Standard Error Bars Shown

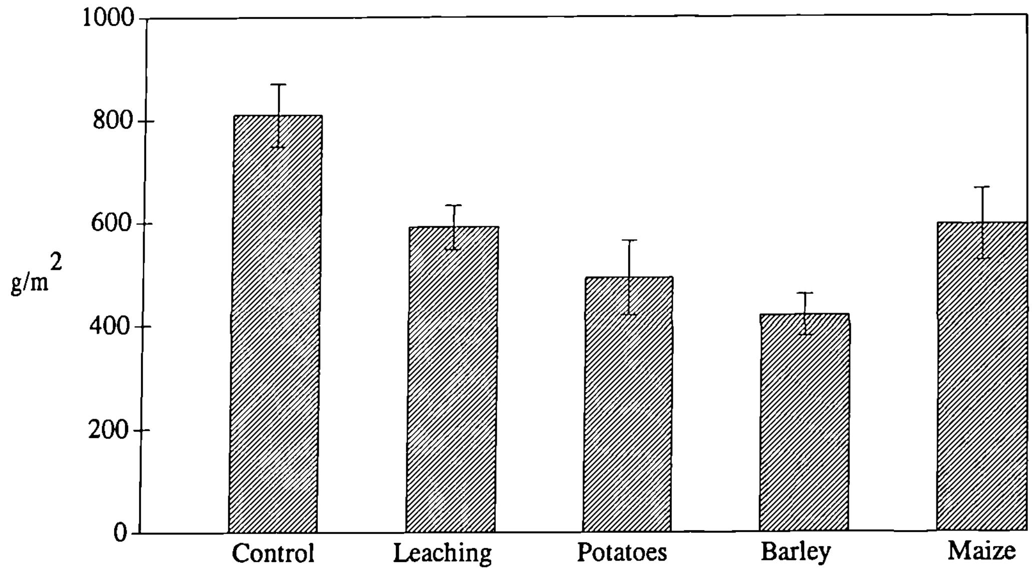


Figure 6.2b: Histogram Showing Mean Standing Crop for the Treatments in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Standard Error Bars Shown

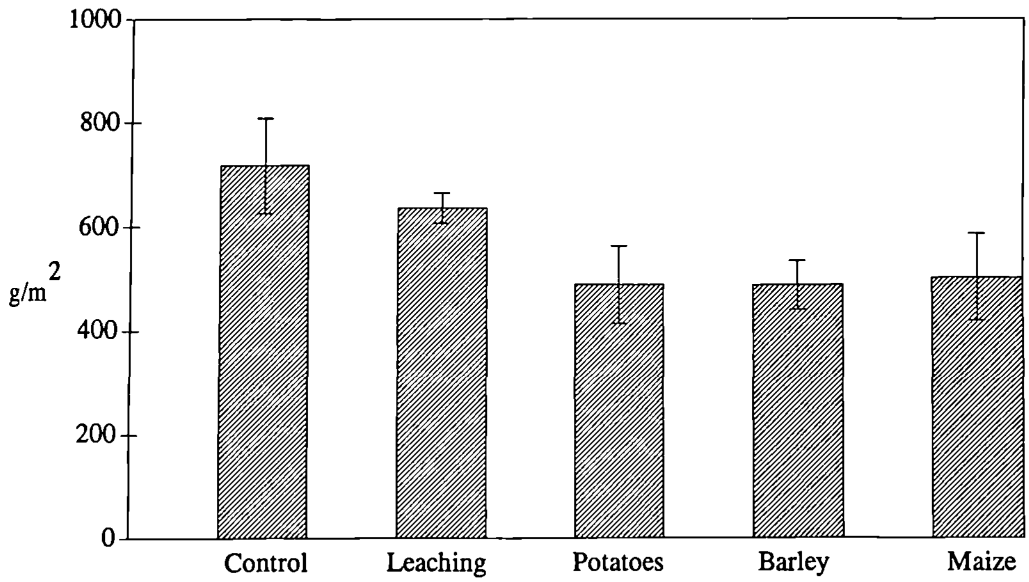


Figure 6.3a: Histogram Showing Mean Standing Crop for the Treatments in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988) with Controls Masked.
Standard Error Bars Shown

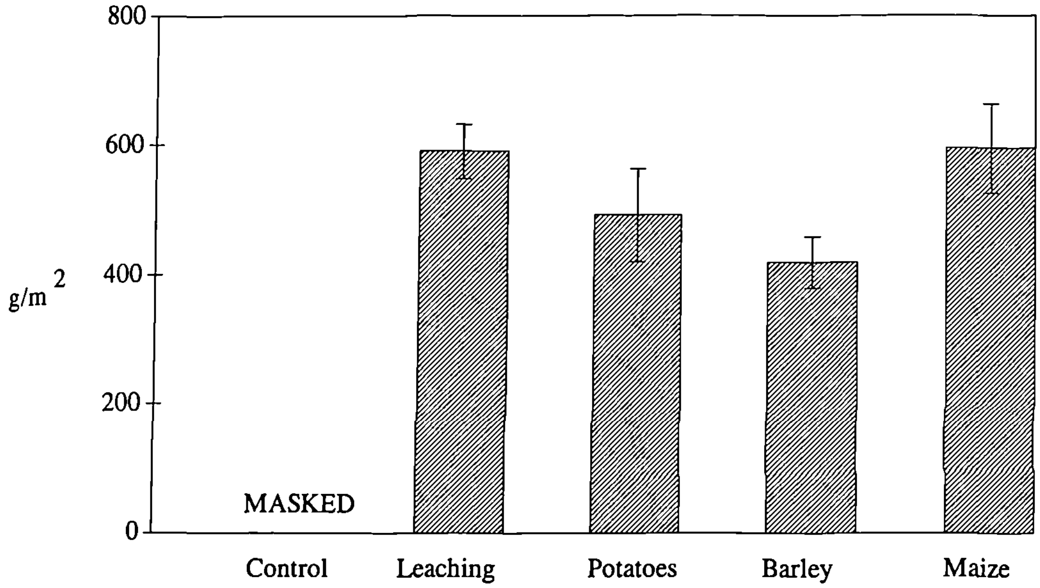


Figure 6.3b: Histogram Showing Mean Standing Crop for the Treatments in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989) with Controls Masked.
Standard Error Bars Shown

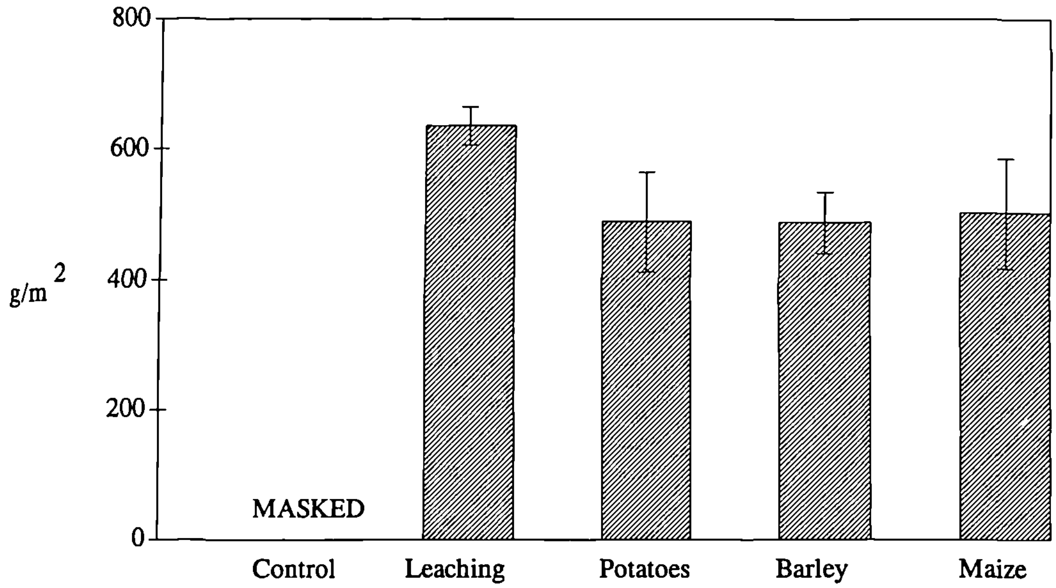


Figure 6.4a: Histogram Showing Mean Standing Crop for the Cropping and Nitrogen Treatments in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Standard Error Bars Shown

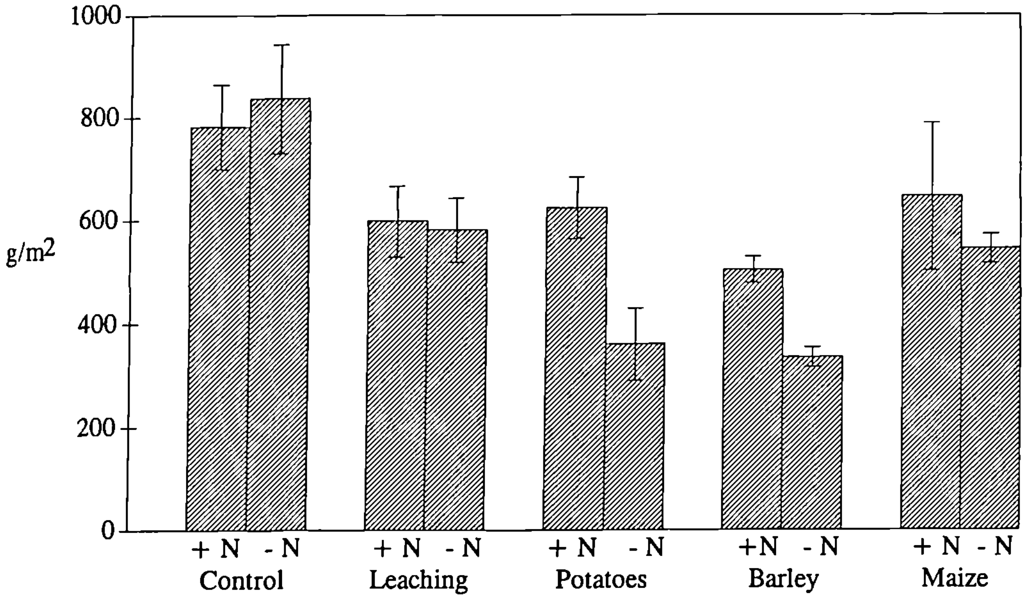


Figure 6.4b: Histogram Showing Mean Standing Crop for the Cropping and Nitrogen Treatments in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Standard Error Bars Shown

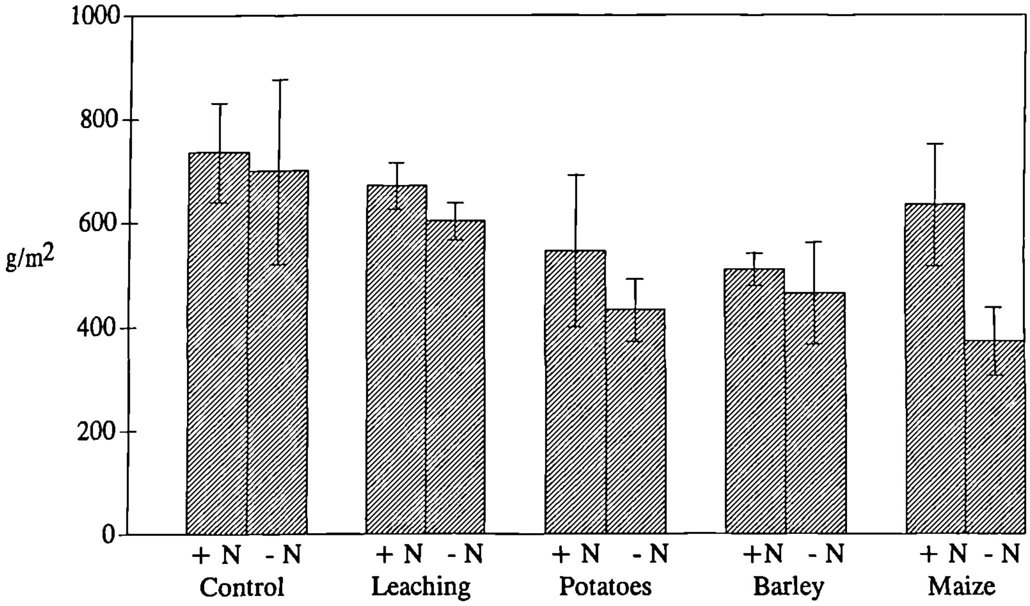


Figure 6.5a: Histogram Showing Mean Standing Crop Values for *Agrostis capillaris* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Standard Error Bars Shown.

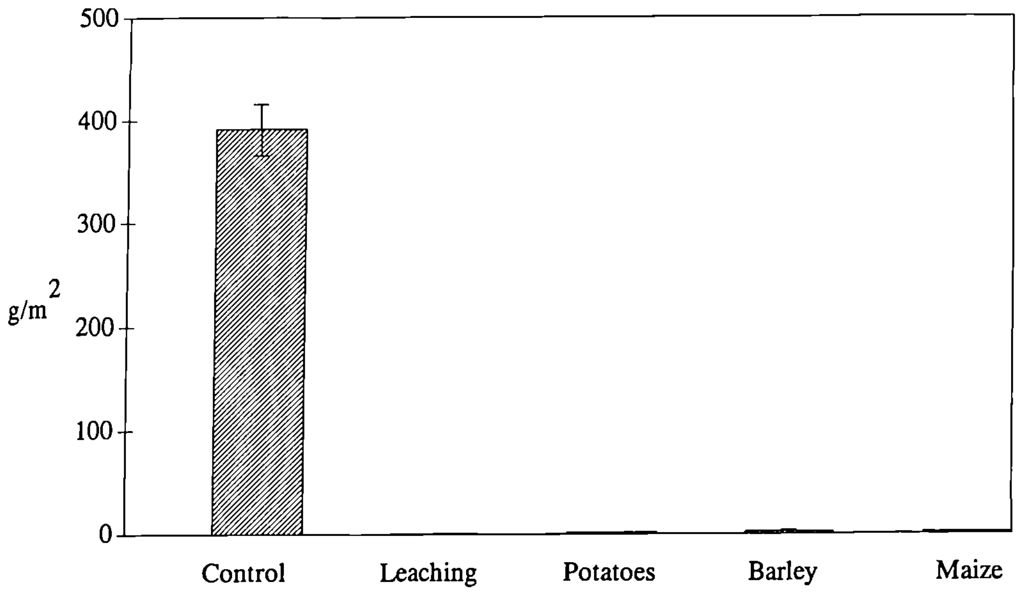


Figure 6.5b: Histogram Showing Mean Standing Crop Values for *Agrostis capillaris* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Standard Error Bars Shown.

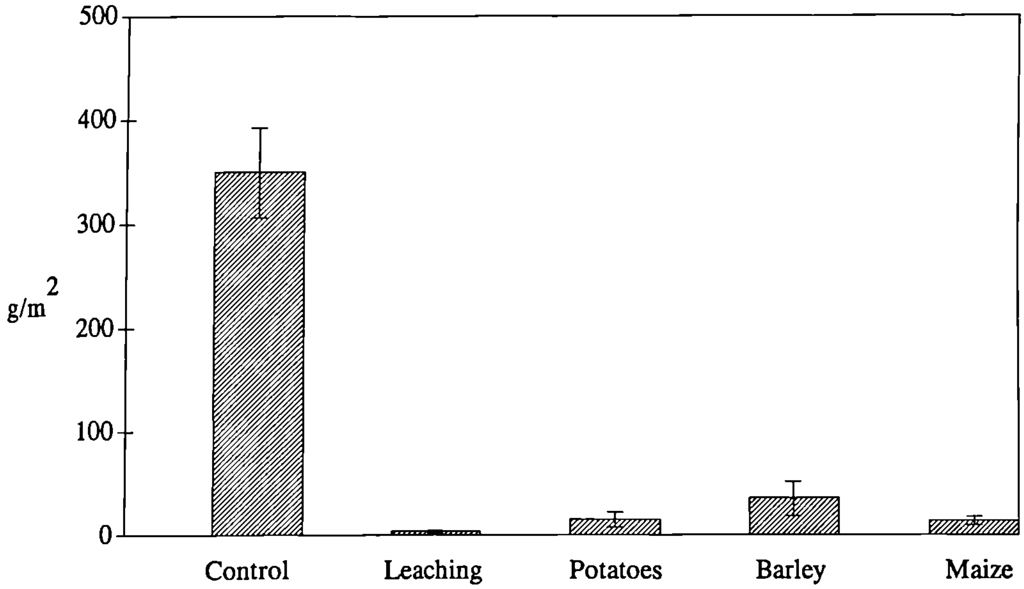


Figure 6.6a: Histogram Showing Mean Standing Crop Values for *Dactylis glomerata* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Standard Error Bars Shown.

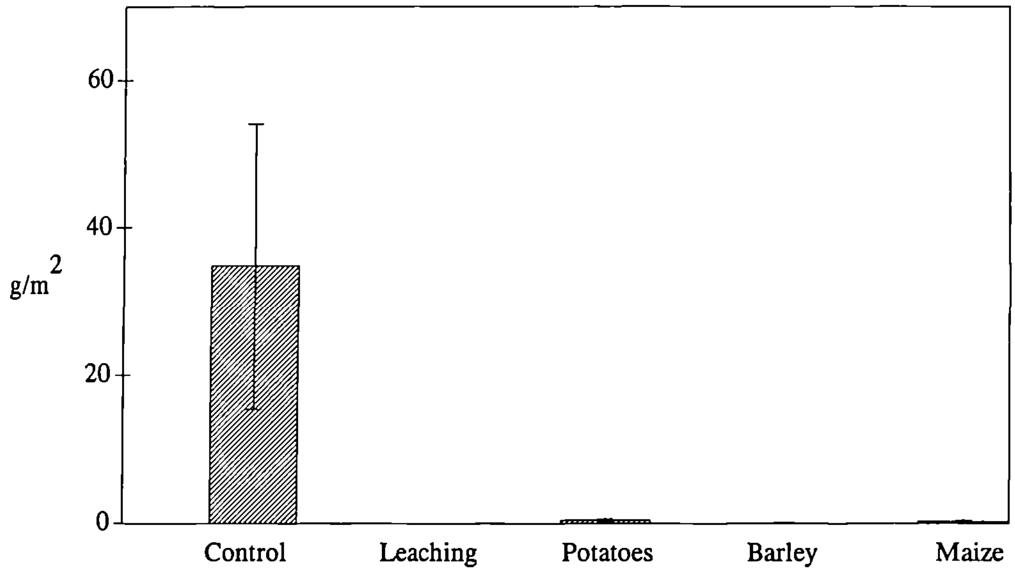


Figure 6.6b: Histogram Showing Mean Standing Crop Values for *Dactylis glomerata* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Standard Error Bars Shown.

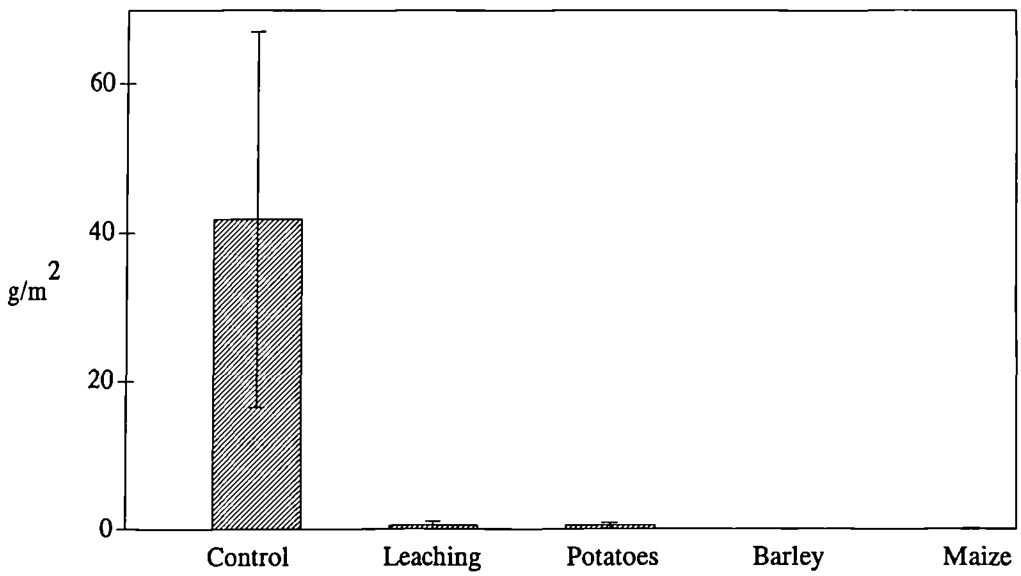


Figure 6.7a: Histogram Showing Mean Standing Crop Values for *Rumex acetosa* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Standard Error Bars Shown.

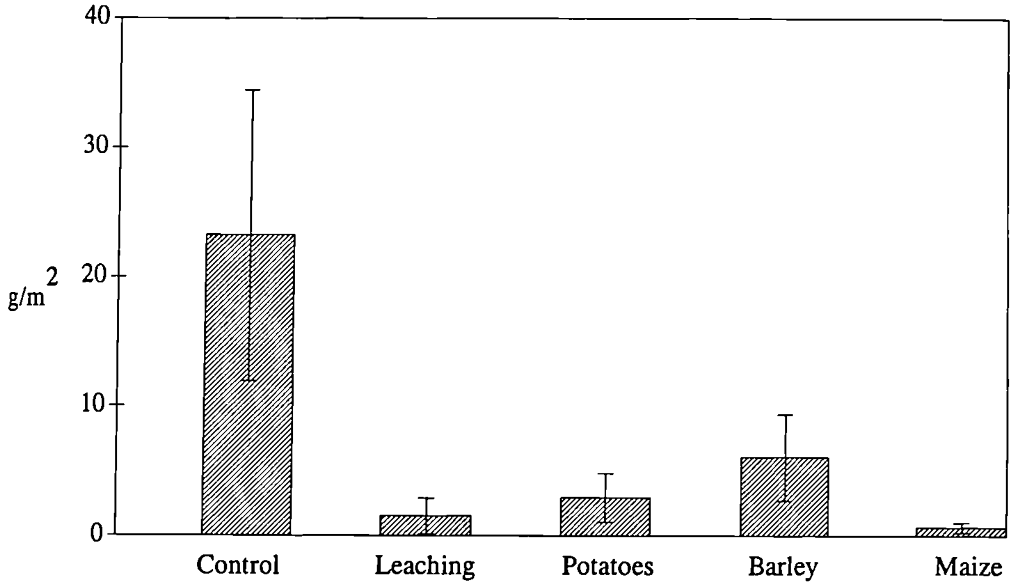


Figure 6.7b: Histogram Showing Mean Standing Crop Values for *Rumex acetosa* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Standard Error Bars Shown.

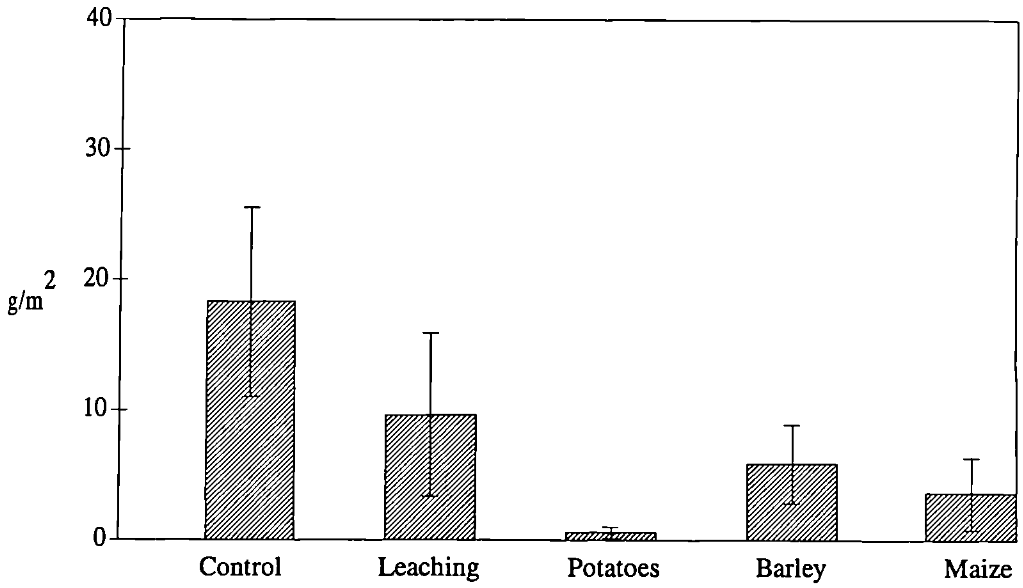


Figure 6.8a: Histogram Showing Mean Standing Crop Values for *Agrostis gigantea* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Standard Error Bars Shown.

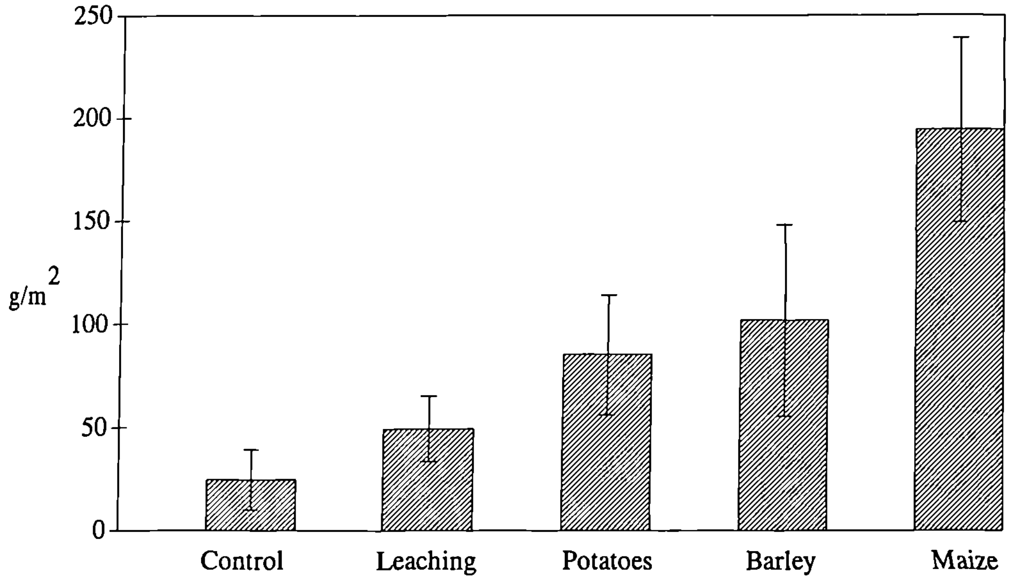


Figure 6.8b: Histogram Showing Mean Standing Crop Values for *Agrostis gigantea* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Standard Error Bars Shown.

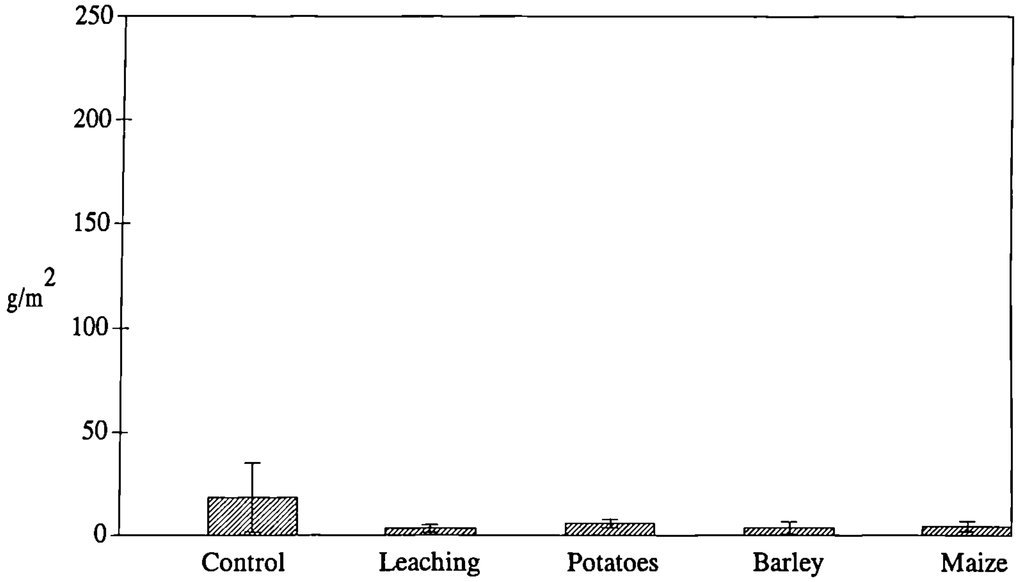


Figure 6.9a: Histogram Showing Mean Standing Crop Values for *Holcus lanatus* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Standard Error Bars Shown.

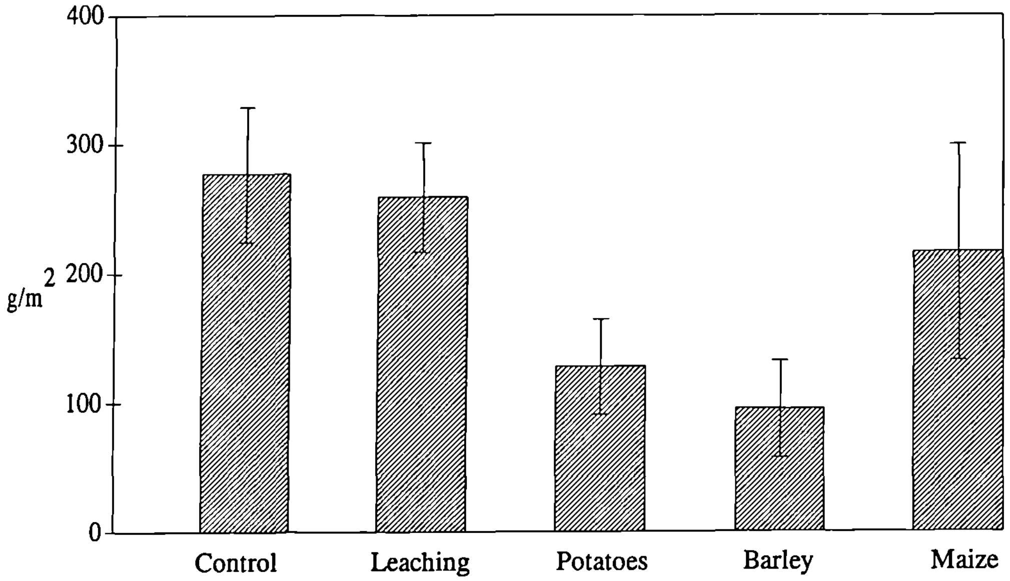


Figure 6.9b: Histogram Showing Mean Standing Crop Values for *Holcus lanatus* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Standard Error Bars Shown.

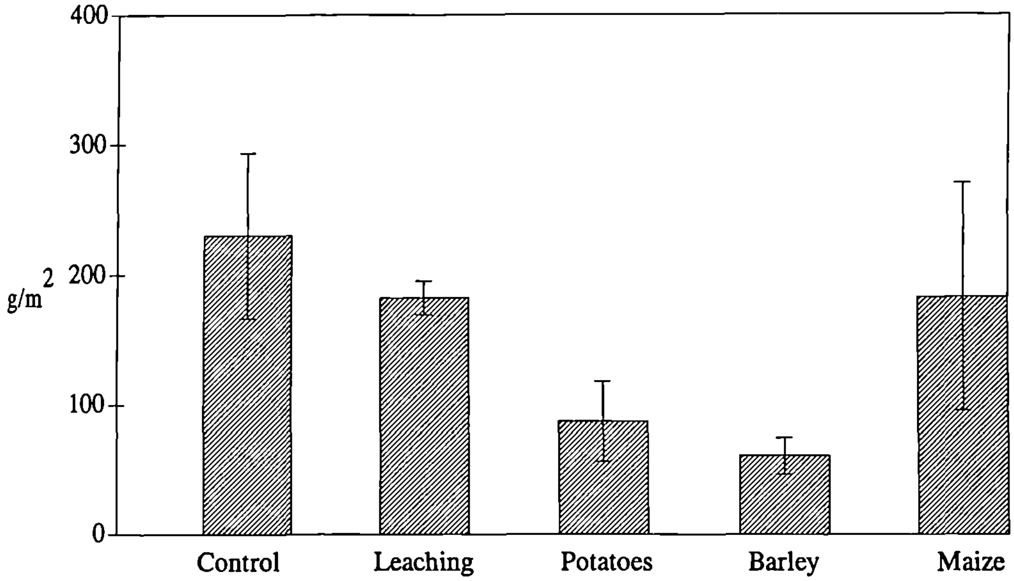


Figure 6.9c: Histogram Showing Mean Standing Crop Values for *Holcus lanatus* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Nitrogen Treatments Shown.
Standard Error Bars Shown.

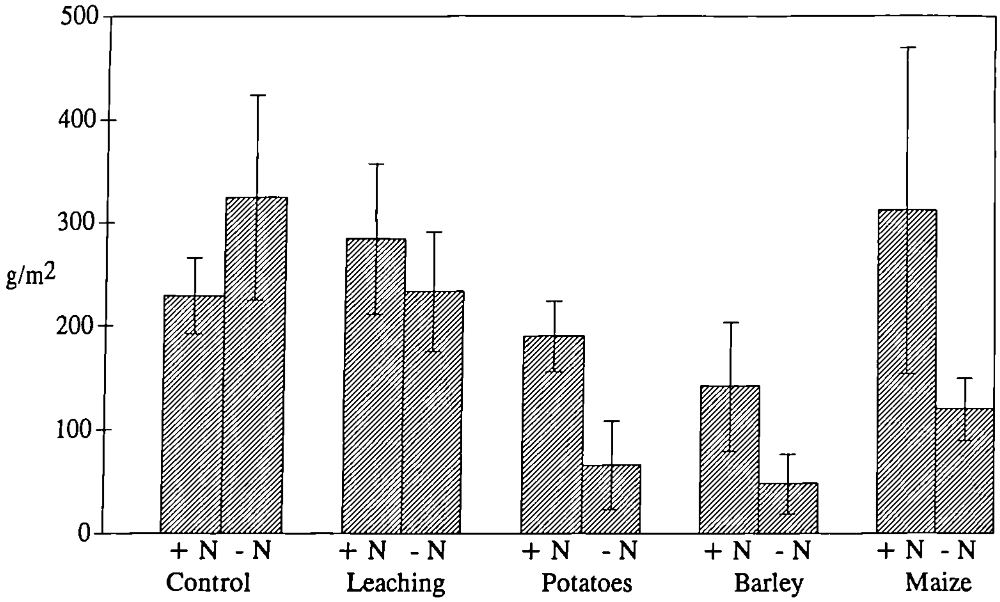


Figure 6.9d: Histogram Showing Mean Standing Crop Values for *Holcus lanatus* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Nitrogen Treatments Shown.
Standard Error Bars Shown.

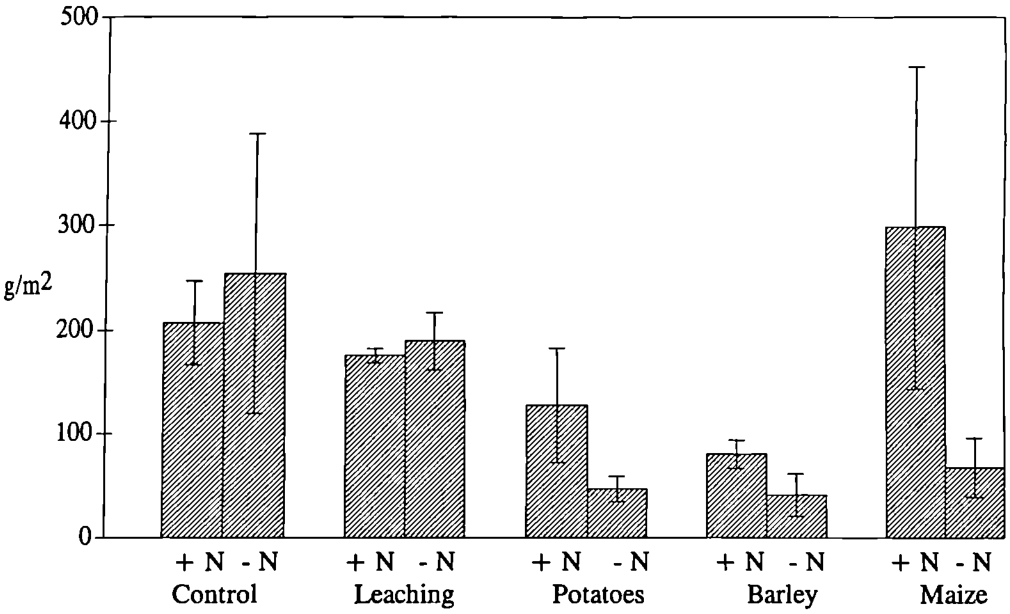


Figure 6.10a: Histogram Showing Mean Standing Crop Values for *Anthoxanthum odoratum* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Standard Error Bars Shown.

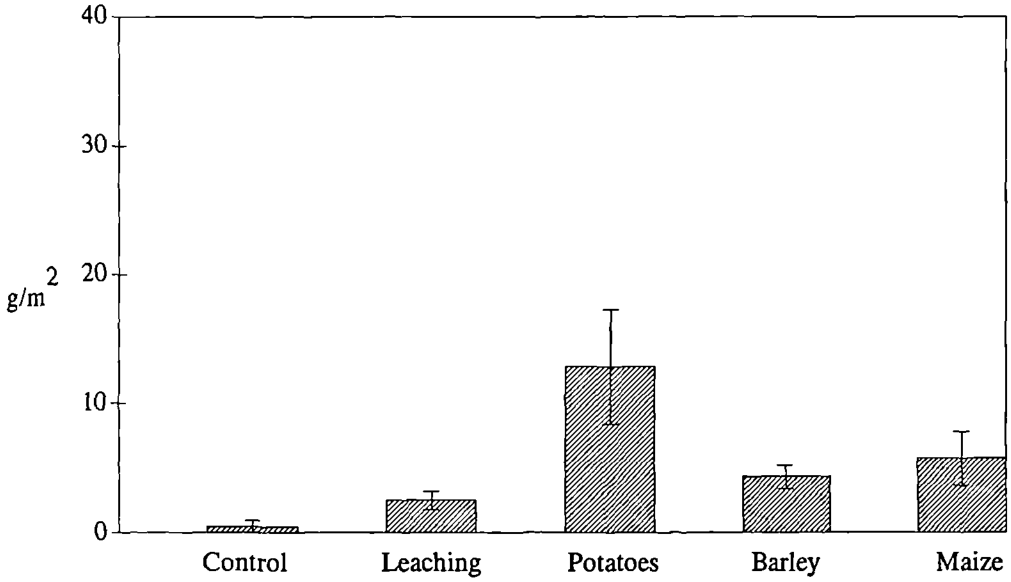


Figure 6.10b: Histogram Showing Mean Standing Crop Values for *Anthoxanthum odoratum* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Standard Error Bars Shown.

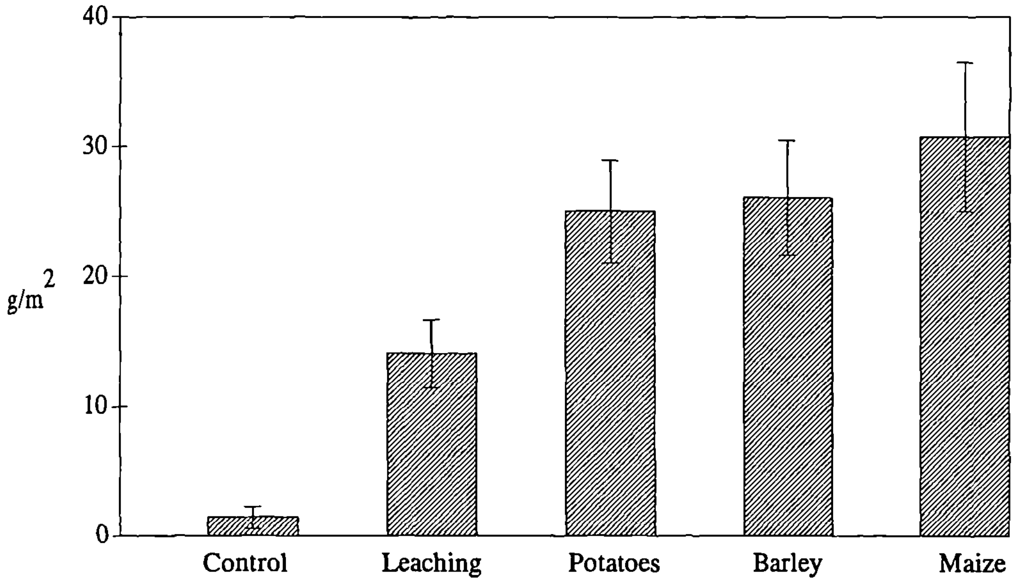


Figure 6.11a: Histogram Showing Mean Standing Crop Values for *Hypochoeris radicata* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Standard Error Bars Shown.

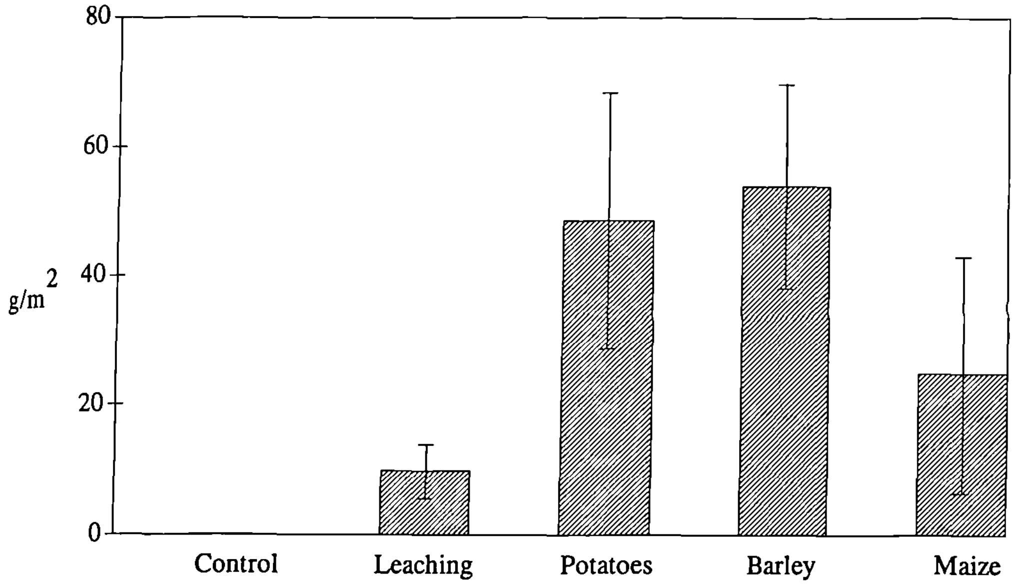


Figure 6.11b: Histogram Showing Mean Standing Crop Values for *Hypochoeris radicata* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Standard Error Bars Shown.

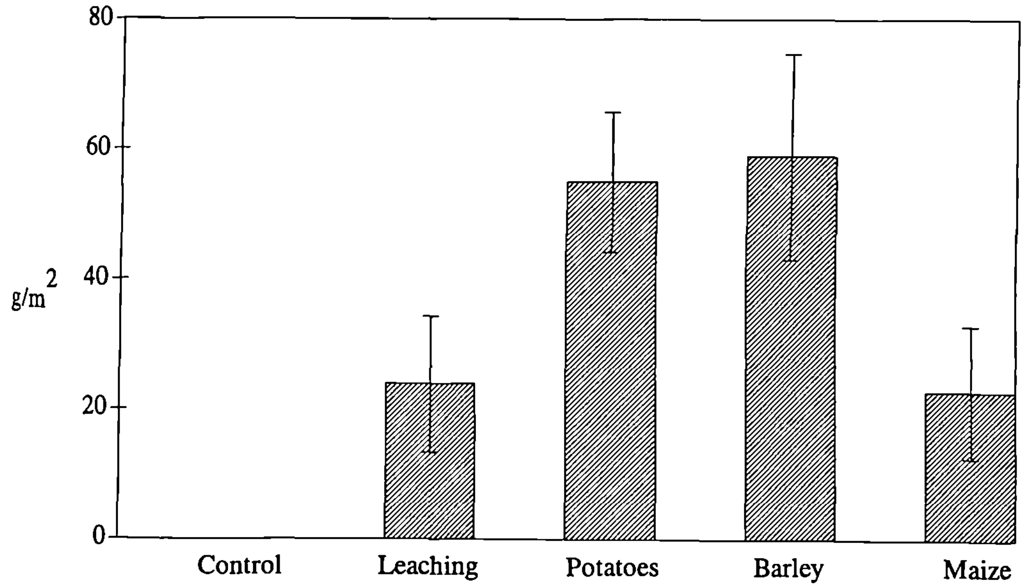


Figure 6.11c: Histogram Showing Mean Standing Crop Values for *Hypochoeris radicata* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Nitrogen Treatments Shown.
Standard Error Bars Shown.

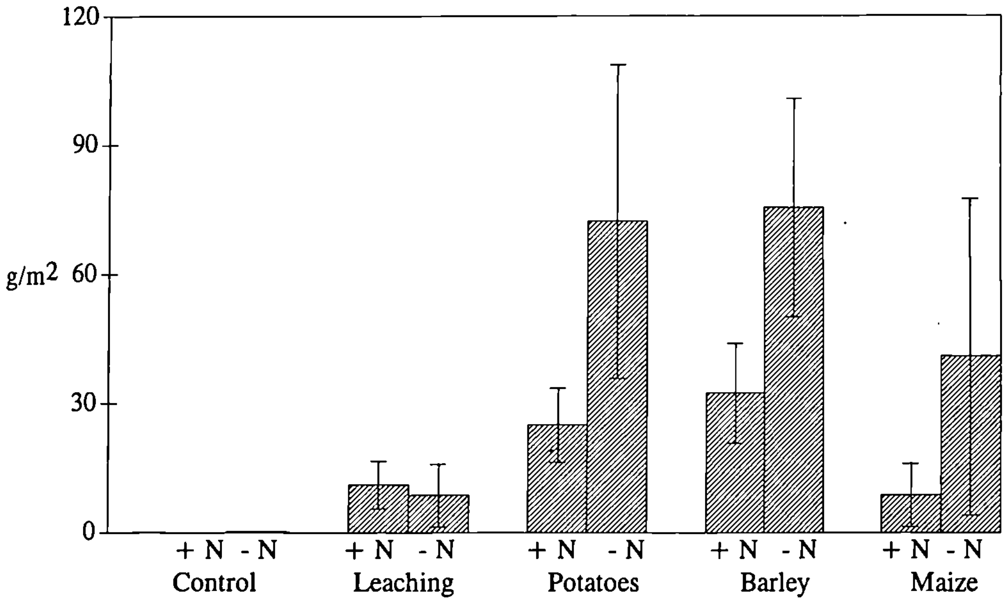


Figure 6.11d: Histogram Showing Mean Standing Crop Values for *Hypochoeris radicata* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Nitrogen Treatments Shown.
Standard Error Bars Shown.

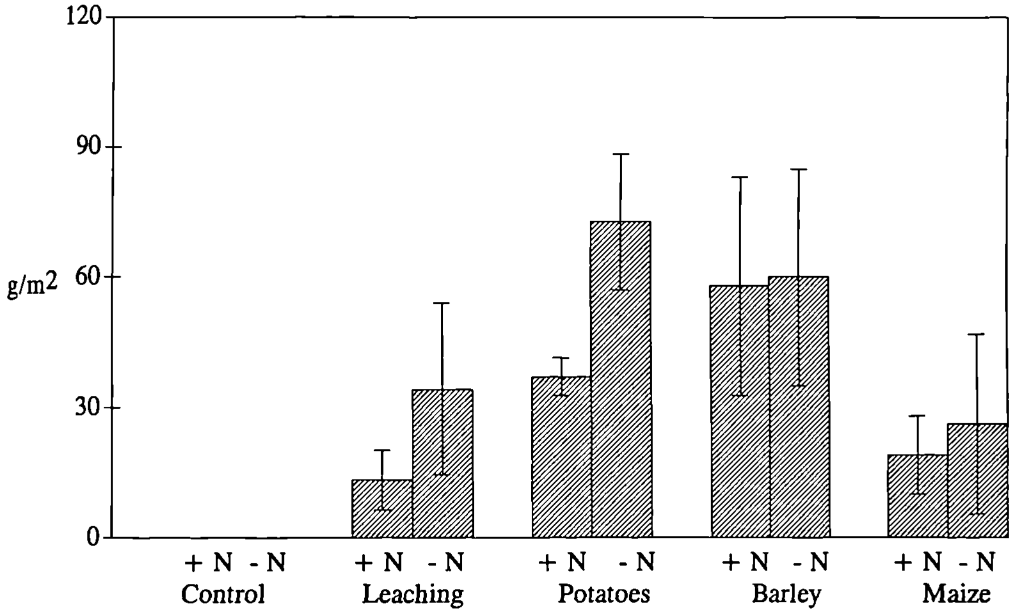


Figure 6.12a: Histogram Showing Mean Standing Crop Values for *Rhinanthus minor* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Standard Error Bars Shown.

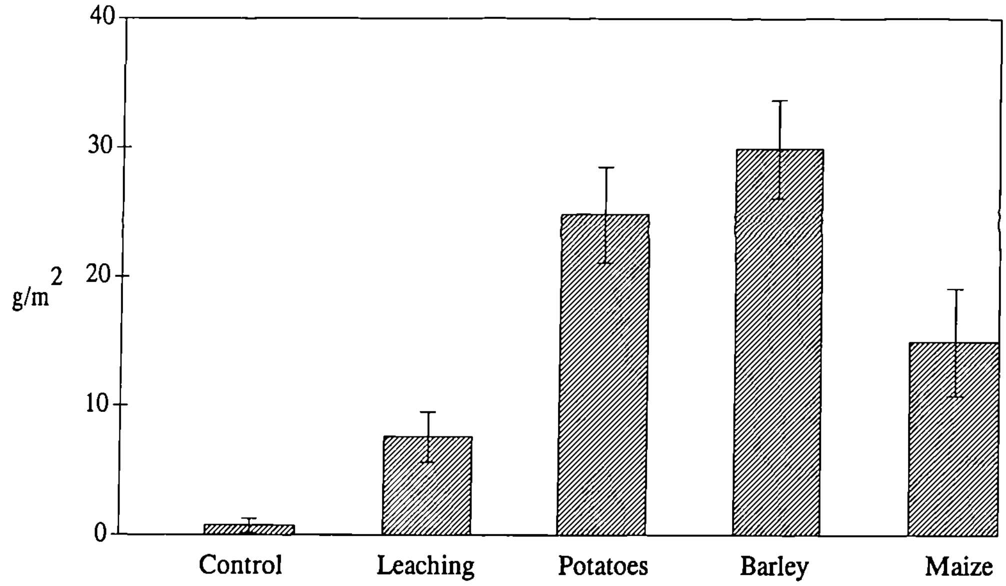


Figure 6.12b: Histogram Showing Mean Standing Crop Values for *Rhinanthus minor* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Standard Error Bars Shown.

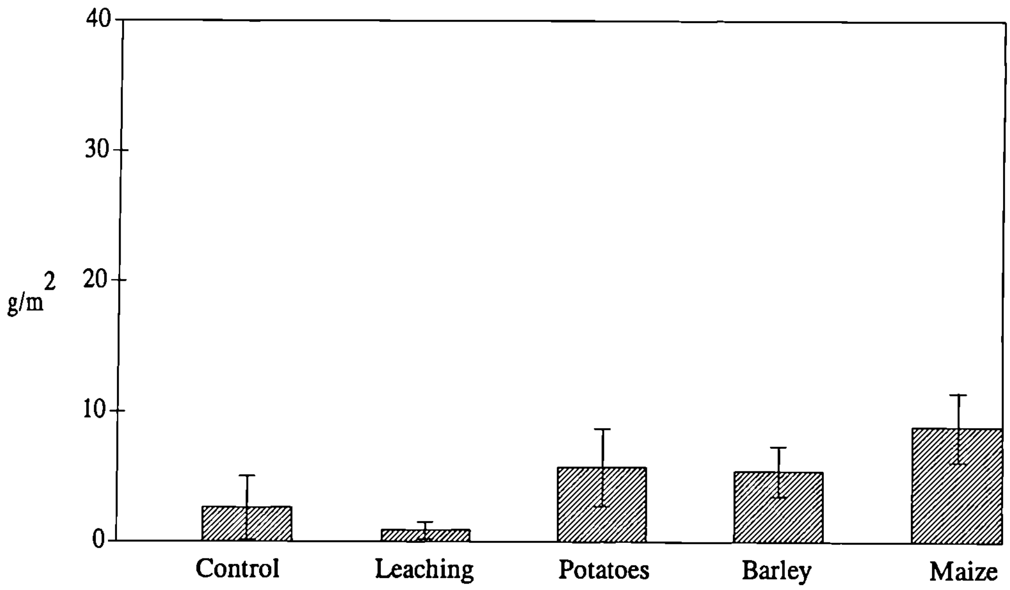


Figure 6.12c: Histogram Showing Mean Standing Crop Values for *Rhinanthus minor* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1988).
Nitrogen Treatments Shown.
Standard Error Bars Shown.

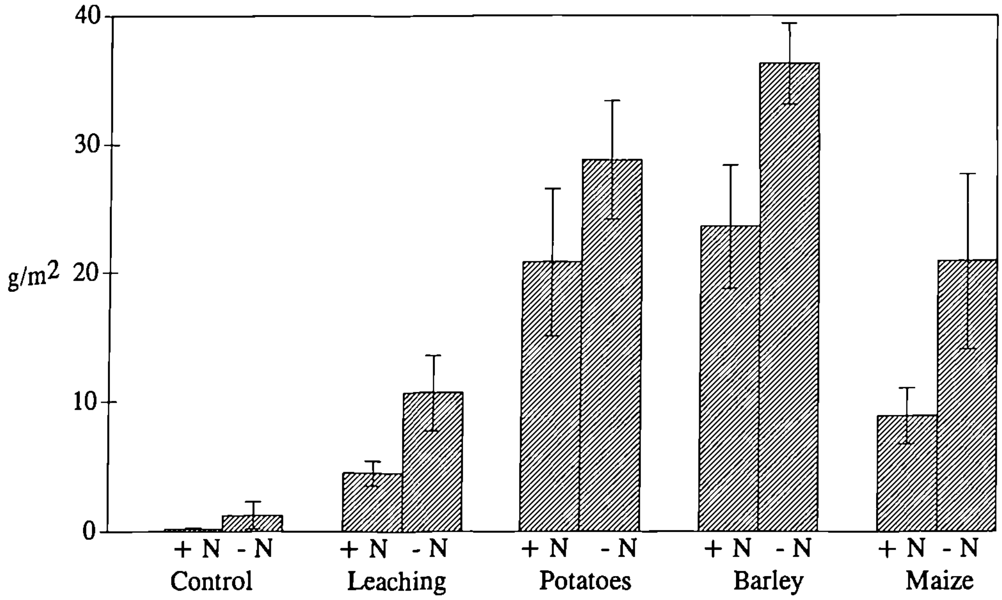
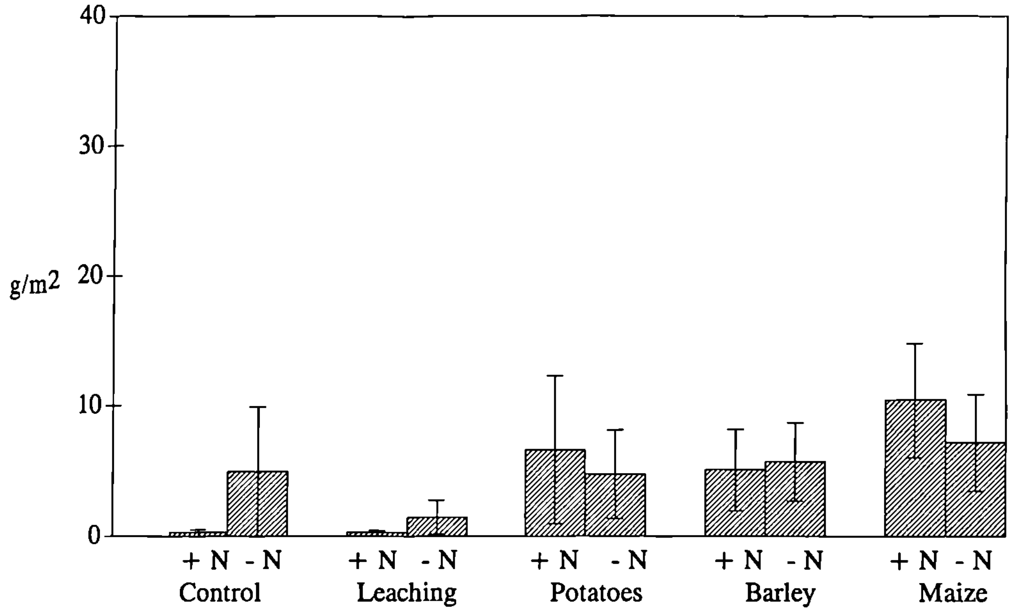


Figure 6.12d: Histogram Showing Mean Standing Crop Values for *Rhinanthus minor* in the Cropping Experiment at Compton Agricultural Unit, Wolverhampton (1989).
Nitrogen Treatments Shown.
Standard Error Bars Shown.



CHAPTER 7

A Comparison of the Use of Wildflower Seed and Hay Strewing During the Creation of Species-rich Grasslands

7.0 A Comparison of the Use of Wildflower Seed and Hay Strewing During the Creation of Species-rich Grasslands

7.1 Introduction

In Chapter 1 it was pointed out that Hopkins (1989) suggests that habitat creation is synonymous, to many people, with grassland creation using wildflower seed. As a consequence of the popularity of seeding with wildflower seed, the market for such seed has grown (Brown, 1989; Wells, 1986 & 1987) and seed merchants have responded by supplying an ever growing range of plant species and seed mixtures to suit every conceivable application.

Despite the general increase in knowledge about the fundamentals of grassland creation and the greater seed availability however, evidence is accumulating to suggest that a high proportion of the large number of projects that have been initiated fail or are of limited success (Jones, 1990). In earlier years this may have been put down to untested theory being translated into planting schemes (Dawe, 1984) although it has recently been suggested that research may now have run ahead of practical application (Jones, 1990).

Under the controlled conditions used during research experiments, where the precise origin and viability of seed is usually known, a moderate to high level of success can be achieved. However, the wider application of grassland creation techniques, for example in landscaping schemes or the creation of nature areas in schools, has often lead to disappointment. There now appears to be a growing resistance among certain professional groups to methods which have proved to be unsuccessful and a sense that the practical use of habitat creation is going 'off the boil'.

There are various reasons for the failure of habitat creation projects. Inappropriate choice of sites due either to site ecology or practical constraints such as lack of access for machinery, faulty project design or poor choice of habitat type for creation, incorrect implementation, and lack of appropriate aftercare and long term management are all common causes of failure. There is also often a lack of understanding of the high level of commitment required if a project is to be successful. This requirement is particularly true for grassland creation using wild flower seed which is one of the most demanding types of habitat creation project in terms of expense, technical expertise and commitment to management.

It has been suggested that it is the type of seed mixture which is often the prime concern of those proposing to carry out a reseeding project, with other aspects receiving little attention

(Hopkins, 1989). However, there is often some question about the composition of available seed mixtures and the viability of seeds within mixtures, adding an extra potential cause of failure to the list already mentioned. Problems have arisen from the inclusion of non-native varieties of some species in seed mixtures. For example 'agricultural' varieties of legumes such as *Trifolium pratense* and *Lotus corniculatus* have often been identified after seeding. Problems have also been reported with the accuracy of the supply from merchants (eg. *Achillea ptarmica* seed ordered by Wolverhampton MBC turned out to be *Achillea millefolium* upon germination).

There are many potential reasons for loss of wildflower seed viability. The methods of seed storage both before and after purchase are critical although the former is out of the control of the purchaser regardless of whether guides to seed storage provided in various publications (eg. Wells *et al*, 1981) are adhered to on receipt of the seed.

In contrast, strewn hay can be used to provide seed of known provenance and seed freshness can generally be guaranteed.

As a comparative test of the two methods (ie. seeding using purchased seed or strewn hay) a simple replicated experiment using both was carried out as part of the present study and is reported in this chapter.

The use of an early season cutting treatment was also investigated as part of the experiment discussed in this chapter. Regular cutting in the first season is often prescribed as beneficial during the creation of meadows using wildflower seed (eg. Baines & Smart, 1984). This approach was not feasible during the present study in view of the limitations on time which required records to be made of the created swards in the first season. Furthermore it would seem that it is inappropriate to maintain a cut sward for an entire season in meadows which support desirable annual species such as *Rhinanthus minor* and *Euphrasia officinalis agg.* An early season cut, on the other hand, may have certain benefits, particularly after a mild winter.

Pennerley Meadows, Shropshire, was used as a donor of hay for the experiment described in this chapter. A survey of the vegetation of the donor meadow has been discussed in Chapter 2.

Wildflower seed was purchased from one of the larger seed merchants. A mixture was designed which contained as many of the species present in the Pennerley Meadows sward as it was possible to obtain. The seed mixture ordered contained seed in relative proportions estimated to be similar to those found naturally in the Pennerley Meadows sward based on their relative abundance at the source meadow and the number of seeds per gram advertised by the seed merchant (Table 7.1: p. 183). The seed was purchased three months prior to seeding and on receipt stored at a temperature of 5 °C (± 1 °C) in a desiccator over silica gel.

7.2 Methods

A small area was delimited at Compton Agricultural Unit, Wolverhampton, close to the experimental area used during the cropping experiment described in Chapter 6. The existing grassland sward at Compton was relatively homogeneous and of limited botanical interest. It had been maintained as permanent grassland for many years with frequent but unquantified applications of fertiliser and lime.

Four treatments were used during the experiment:

i) Strewn hay - cut in spring
ii) Strewn hay - uncut
iii) Seed mixture - cut in spring
iv) Seed mixture - uncut

Three replicates of each of the four treatments were established in 3m x 3m plots distributed randomly in a block measuring 9m x 12m (Figure 7.1: p. 194). No borders were left between treatments although only the central 2m x 2m were assessed to reduce any edge effects between the treatments.

Soil samples were collected from the experimental plots and chemical analyses for nitrate, ammonium, available phosphorus and available potassium were carried out in order to confirm the uniformity of the soil between the plots. Standard analytical methods were used (Ministry of Agriculture, Fisheries and Food, 1986).

The existing grassland vegetation in the experimental plots was killed using glyphosate. The plots were then rotovated and harrowed to produce a suitable seed bed.

Pennerley Meadows were cut on the 3 August 1987 and on the following day the hay was big baled and transported to Wolverhampton as described in Chapters 5 & 6. A small, approximately equal, quantity of hay was spread thinly on each of the six hay plots to just cover the bare soil. The hay was allowed to dry for several weeks during which time it was carefully turned by hand to encourage the seed to drop. The hay was then carefully removed from the experimental area.

On 20 August the remaining six plots were seeded with the purchased seed mixture at a rate of 40kg/ha (4g/m^2) as is recommended for other commercially available seed mixtures.

The plots were not weeded once seeded and were left until March 1988 when, just before the predicted germination of *Rhinanthus minor*, the relevant plots were cut at a height of approximately 5cm and the clippings removed. The hay was then allowed to grow until early/mid August when the hay crop was cut using a tractor mounted reciprocating blade mower. The hay was allowed to dry, turned and baled using a conventional (square) baler. Following the initial hay cut the plots were mown regularly (approximately once every three to four weeks) until the end of the season.

The following year (1989) the hay was managed in the same way although no early season cuts were made in any plot.

The plots were surveyed in late July in both 1988 and 1989.

In 1988 the 3m x 3m plots were trimmed to 2m x 2m using an Allen Scythe and rotary mower. The central 4m^2 was then divided into four 1m x 1m plots and a record made of species present and their relative abundance using the Domin scale.

In 1989 the plots were again trimmed from 3m x 3m to 2m x 2m using the same equipment. The central 4m^2 was then treated as a single 2m x 2m quadrat and the species present and their relative abundance recorded in the same way as for 1988.

The simple nature of the data obtained during the experiment required little use of analytical techniques although TWINSPAN (Hill, 1979a), as provided in the VESPAN package (Malloch, 1990), was used to compare the vegetation of the different experimental plots.

TWINSPAN (Two Way INdicator SPecies ANalysis) is a polythetic, divisive classification technique developed from, and generally superseding, ISA described in Chapter 3. The basis of the analysis is as described in Chapter 3 although TWINSPAN has been developed to produce species, as well as stand, classifications. The general advantages of TWINSPAN over other classification techniques for the interpretation of ecological data have been described by a number of authors (eg. Gauch, 1982; Pielou, 1984).

TWINSPAN operates on a semi-quantitative level and adopts the concept of pseudospecies such that for each species there are a given maximum number of pseudospecies each representing part of the quantitative range for that species. Domin scores are the default quantitative values used in TWINSPAN as presented in the VESPAN package and the four default pseudospecies cut-levels are:

Pseudospecies cut-level 1	= domin range	1-2
Pseudospecies cut-level 2	= domin range	3-4
Pseudospecies cut-level 3	= domin range	5-7
Pseudospecies cut-level 4	= domin range	8-10

These default pseudospecies cut-levels were adopted during the use of TWINSPAN in the present study.

Analysis of variance, as described in Chapter 6, was used to test for significant variation in the soils between the different experimental plots.

7.3 Results

Chemical analysis indicated that the soils were fairly uniform between the various experimental plots in terms of the availability of major plant nutrients (Table 7.2: p. 184). Analysis of variance indicated that there were no significant differences between the various plots in terms of the parameters measured.

The grassland sward that developed in the experimental area did not appear to be uniform, but varied visibly between treatments. The plots which had received hay supported a sward that, although dominated by *Holcus lanatus*, contained a range of other species including finer grasses such as *Agrostis capillaris* and *Festuca rubra*, with colour and diversity being added by the inclusion of species such as *Leucanthemum vulgare*. The sward was typical of that which had become established in other experimental areas in Wolverhampton when Pennerley Meadows had been used as a donor of seed.

The plots seeded using the purchased mixture were noticeably less colourful. They too were dominated by *Holcus lanatus*, although in these plots this species was vigorous and the sward was rank. Other grasses and forbs were a much less significant component of the vegetation although closer inspection showed some to be present.

A summary of the quantitative data recorded in both 1988 and 1989 is presented in Tables 7.3 (p. 185) and 7.4 (p. 187). To aid presentation of the results, species have been ordered according to their frequency at Pennerley Meadows in the same format as used in Chapters 3, 4 and 5.

The results presented in Table 7.3 (p. 185) shows that in 1988 most of the species recorded in frequency class V at Pennerley Meadows had become established in the hayed plots at frequencies comparable with the donor meadow, although there were several noticeable exceptions. *Cynosurus cristatus* was recorded at only a very low frequency level whilst *Dactylis glomerata* and *Trifolium pratense* were not recorded at all. This seems unusual as these species had been successfully introduced during other experiments using hay from Pennerley Meadows. It is possible that they may have been overlooked in the created sward during the survey undertaken in the first year. This conclusion was borne out for *Cynosurus cristatus* and *Trifolium pratense* as both species were recorded during the survey undertaken in the second season (1989), the former at high levels of frequency. *Dactylis glomerata*, however, remained absent in the second season and it seems likely that this species was not introduced in the small amount of hay used to seed the experimental plots.

As suggested by the observations made of the experimental area prior to undertaking the quantitative recording, the seeded plots were altogether less successful in terms of supporting species which were the most frequent in Pennerley Meadows, all of which were included in the seed mix order. In these plots only *Holcus lanatus* and *Festuca rubra* were present at a frequency of over 80% (frequency class V). However, of these two species, the latter was present only at low levels of abundance (domin range 1-2) whilst the former was very abundant and formed an almost 100% cover in several plots (domin range 9-10). Other fine grasses (*Agrostis capillaris*, *Anthoxanthum odoratum*, and *Cynosurus cristatus*) were either absent or present at much lower levels of abundance than at Pennerley Meadows. *Leucanthemum vulgare* was restricted to a few individual plants whilst *Hypochoeris radicata*, although frequent, was not abundant in terms of its domin score.

It is clear that in 1988 there was little difference between the plots seeded with hay and those in which the purchased seed mixture was used in terms of the less frequent species in the donor meadow (frequency classes I to IV) although species such as *Ranunculus acris* and *Centaurea nigra* were more frequent in the hayed plots.

The plots of both treatments supported a similar complement of additional (weed) species (ie. those which had established naturally, not having been introduced by seed or hay). However, an interesting observation made as the grassland swards began to establish was that, unlike the hayed plots, the plots seeded with the purchased mixture supported an abundance of weed species from an early stage. The cover of hay apparently suppressed the development of the weed flora in the initial stages of seed germination and meadow establishment. Although weed abundance was ultimately similar in both treatments, it seems probable that their initial suppression enabled the introduced meadow species to germinate and establish in a relatively competition free environment.

Overall the hayed plots were more diverse than the plots seeded with the purchased mix in 1988, both in terms of total number of species and mean number of species per quadrat.

By 1989, the second season after the establishment of the grassland plots, the hayed plots had improved in terms of mean number of species per quadrat and their species compliment. This was despite a fall in total number of species which was generally a reflection of the reduced number of additional weed species recorded.

Holcus lanatus remained frequent in the hayed plots in the second season although the level of abundance of this species was slightly reduced, reflecting the trend in meadow development observed in other meadows created using the hay strewing technique with hay from Pennerley Meadows.

However, the sward in the plots seeded with the purchased seed mix remained dominated by *H. lanatus* to the near exclusion of other species. *Agrostis capillaris* was more frequent in these plots in the second year but *Festuca rubra* had all but disappeared. Other constant species in the Pennerley Meadows sward remained infrequent or absent and the created sward appeared to be deteriorating.

The difference between the grassland swards which became established in the plots using the two different approaches was borne out by TWINSPAN. The first division of the analysis of the 1988 data made a distinction between the two treatments by grouping the 24 quadrats recorded in the hayed plots separately from those recorded in the plots seeded with the purchase seed mixture. The same distinction was also made in the 1989 data when the hayed and seed mixture plots were again separated into separate groups at the first TWINSPAN division.

The early season cutting treatment appeared to have little effect on the nature and composition of the grassland sward that established in the experimental treatments regardless of whether the hay or seed mixture were used as the seeding medium (Tables 7.5: p. 189 and 7.6; p. 191). It should be noted, however, that the plots seeded with the seed mixture and which were cut in spring contained both a higher number of species and mean number of species per quadrat in the first year compared to the un-cut plots. This situation persisted into the second season and it looks possible that the cutting treatment did have a beneficial effect in these plots. Had the cutting treatment been continued for the first season it is possible that the *Holcus lanatus* would have been suppressed and a more diverse sward may have become established.

TWINSPAN failed to make a distinction between the cut and uncut plots for either the hayed or seed mix plots. The groupings formed by the second division of the analysis were produced as a result of subtle, possibly random, variations in the species present which are not easily explained and did not correspond to the cutting treatments. This further suggests that the single cutting treatment had little beneficial effect on the created sward.

7.4 Discussion

The results of the experiment clearly show that the grassland swards which became established in the various plots differed according to which method of seeding was used. The plots seeded using the purchased seed mixture failed in terms of producing a diverse grassland sward and there was little similarity with Pennerley Meadows which had been the model used to formulate the seed mixture.

The hayed plots were more successful and a sward developed which contained the characteristic species of the Pennerley Meadows sward. With sensible management the grassland in these plots should continue to improve and possibly diversify as seed introduced into the soil seed bank germinates.

The use of strewn hay has disadvantages when compared with the use of purchased seed during meadow creation projects. It is potentially labour intensive, there is an added transport cost and a suitable and available donor of hay needs to be found. However, once one meadow has been successfully established and supports a range of the more characteristic species of the grassland community, it provides a source of seed which can be used during other meadow creation schemes. This approach has been adopted in Wolverhampton at the Bushbury Hill site discussed in Chapter 4 where the local authority have used the hay from the original meadow to extend the area of the open space put down to this vegetation with a reasonable level of success. This work will be discussed elsewhere.

The use of seed mixtures may have disadvantages over and above the potential failure of the seeds to germinate experienced in the experiment discussed here. Seed mixtures are generally expensive and a complex mixture, such as that used in the experiment at Compton, may be prohibitively so. The complexity of the ordered mix used here resulted in an extremely high price at £120/kg (cf. the 'Cricklade' mix, harvested from North Meadow, Cricklade and available commercially was, at the time of the experiment, available from the same seed merchant at £40/kg). Therefore, at an average sowing rate of approximately 40kg/ha, the price of seed mixtures can far exceed the combined transport, labour and other costs involved when using hay strewing on a reasonable sized site. Seeding costs using the hay strewing approach were approximately £275 per acre during the present study when big bales were used. This is comparable to Stevens' (1988) figure of £565/ha for purchase, cutting, loading, transport and spreading of green hay during the creation of Rajna's Meadow, Dorset using the hay strewing approach with unbaled hay.

There are clear drawbacks to making comparisons between the use of hay strewing and commercially available wildflower seed mixtures on the basis of the experiment described in this chapter. The mixture used was clearly inferior to the Pennerley Meadows hay as a inoculum for grassland creation. However this may be as much related to the fact that the actual seed mixture used was of poor quality as it is related to the advantages of hay strewing over other methods of grassland seeding.

However, it is fair to say that the poor quality of the supplied seed mixture may be one of the most important causes of failure in many grassland creation schemes. Although it maybe an unfair criticism, it has been intimated by some that due to the typical chain of responsibilities in local authorities, meaning that the person responsible for the design of schemes using purchased seed is usually not the same person responsible for the seeding and maintenance of the seeded areas, the failure of such schemes may go unnoticed potentially allowing unscrupulous seed merchants to 'dispose' of older seed stock.

Obviously seed mixtures have been used successfully during habitat creation schemes although in many cases the objectives have been somewhat simpler than to produce a copy of a semi-natural model as has been attempted during the present study with strewn hay.

Wells *et al* (1989) suggest that it is valid in many circumstances to sow simple mixtures of species to create colourful communities which may not be representative of any semi-natural grassland. They suggest a number of criteria which should guide the selection of species for inclusion in wildflower mixtures:

- species should be ecologically suitable for particular soil/water conditions,
- they should be common grassland species,
- they should not be rare or locally distributed,
- they should preferably be perennial and long-lived,
- they should be those with colourful and attractive flowers,
- they should be attractive to insects as nectar or pollen sources,

- they should not be highly competitive or invasive, and
- they should be those species with seed which germinates easily over a range of temperature conditions and preferably without dormancy mechanisms.

Baines (1989) has tried to disentangle the mixed objectives inherent in meadow creation. He made a distinction between 'political' habitat creation where the aims are to improve dire ecological circumstances, simplicity and to maximise attractiveness, and 'ecological' habitat creation where one attempts to create a comprehensive replica of the original.

Although, in most cases the use of purchased seed mixtures has been according to Wells *et al* criteria with the first of Baines' objectives in mind, the use of strewn hay goes some way to satisfying both political and ecological objectives simultaneously. Indeed, as the factors controlling the stability of diverse vegetation are inadequately understood, it may be advisable to attempt to reproduce vegetation types which do actually exist and in which diversity is maintained by identifiable agricultural techniques.

Experience suggests that a more or less instant effect can be achieved using the hay strewing technique, with a colourful and 'politically satisfying' sward often being achievable within one season and a recognisable grassland community type developing thereafter.

In previous experiments in Wolverhampton, there has been no need for the maintenance of the establishing sward in a mown condition for the first season as has been recommended for meadows created using purchased seed, meaning that a simple and regular management regime can be established from the start of a project. Furthermore, annual members of semi-natural grassland swards such as *Rhinanthus minor* and *Euphrasia sp.* can be introduced with some degree of success. The use of hay strewing is therefore a technique which is worthy of further investigation as a viable alternative to the more traditional approach to grassland creation.

TABLES

Table 7.1: The relative proportions of the seed of different species in the seed mixture ordered for use in the experiment comparing seeding using purchased seed and strewn hay.

Species	% of mix by weight
Achillea millefolium	0.1
Agrostis capillaris	1.1
Anthoxanthum odoratum	0.9
Bellis perennis	0.1
Briza media	0.4
Campanula rotundifolia	<0.1
Centaurea nigra	2.2
Cerastium fontanum	2.2
Conopodium majus	4.3
Cynosurus cristatus	1.5
Dactylis glomerata	2.2
Euphrasia officinalis	0.4
Festuca rubra	21.6
Hieracium pilosella	0.2
Holcus lanatus	4.3
Hypochoeris radicata	3.5
Leontodon hispidus	0.2
Leucanthemum vulgare	2.2
Linum catharticum	<0.1
Lotus corniculatus	3.7
Luzula campestris	0.2
Plantago lanceolata	12.9
Prunella vulgaris	0.1
Ranunculus acris	1.7
R. bulbosus	9.1
Rhinanthus minor	8.6
Rumex acetosa	0.7
Trifolium dubium	0.1
T. pratense	10.8
T. repens	1.5
Trisetum flavescens	0.7
Veronica chamaedrys	0.1
Vicia cracca	2.2
Viola arvensis	0.1

Table 7.2: Soil analysis results for the hay versus seed experiment.

Treatment		NO_3 (mg/kg dry soil)				
		Replicates A	B	C	Mean	S.E.
Hay	+ Top	0.5	3.3	1.5	1.77	0.82
	- Top	0.5	5.3	0.5	2.10	1.60
Seed	+ Top	3.9	1.4	1.2	2.17	0.87
	- Top	3.0	1.9	1.5	2.13	0.45

Treatment		NH_4 (mg/kg dry soil)				
		Replicates A	B	C	Mean	S.E.
Hay	+ Top	1.1	2.3	0.5	1.30	0.53
	- Top	1.4	2.3	0.5	1.40	0.52
Seed	+ Top	3.9	0.5	1.0	1.80	1.06
	- Top	2.0	2.2	1.0	1.00	0.37

Treatment		Available Phosphorus (mg/l)				
		Replicates A	B	C	Mean	S.E.
Hay	+ Top	13.0	15.0	16.0	14.67	0.88
	- Top	13.0	6.0	16.0	11.67	2.96
Seed	+ Top	13.0	14.0	18.0	15.00	1.53
	- Top	8.0	10.0	11.0	9.67	0.88

Treatment		Available Potassium (mg/l)				
		Replicates A	B	C	Mean	S.E.
Hay	+ Top	69.0	68.0	63.0	66.67	1.86
	- Top	70.0	51.0	56.0	59.00	5.69
Seed	+ Top	47.0	59.0	70.0	58.67	6.64
	- Top	47.0	49.0	53.0	49.67	1.76

Note that in the above table a value of 0.5 is used where analysis produced a result of <1.0.

Table 7.3: Floristic table for plots in the experiment comparing hay strewing and purchased seed mixture in 1988
a = frequency class, b = domin range.

Species	PENNERLEY		EXPERIMENTAL TREATMENTS			
			Hay		Seed	
	a	b	a	b	a	b
Agrostis capillaris	V	(2-8)	IV	(1-3)	I	(2-3)
Anthoxanthum odoratum	V	(2-4)	V	(2-4)	-	-
Cynosurus cristatus	V	(1-5)	I	(1)	I	(1)
Dactylis glomerata	V	(1-5)	-	-	-	-
Festuca rubra	V	(5-9)	V	(2-5)	V	(1-2)
Holcus lanatus	V	(1-8)	V	(4-9)	V	(9-10)
Hypochoeris radicata	V	(1-4)	V	(2-5)	IV	(1-2)
Leucanthemum vulgare	V	(1-6)	V	(2-5)	II	(1)
Plantago lanceolata	V	(2-7)	V	(1-4)	I	(1)
Ranunculus bulbosus	V	(1-4)	IV	(1-2)	-	-
Rhinanthus minor	V	(1-7)	V	(1-3)	-	-
Trifolium pratense	V	(1-6)	-	-	I	(2)
Briza media	IV	(1-4)	-	-	-	-
Hieracium pilosella	IV	(1-5)	I	(1)	-	-
Rumex acetosa	IV	(1-5)	I	(1-2)	III	(1-2)
Trifolium repens	IV	(1-5)	III	(1-2)	II	(1-2)
Trisetum flavescens	IV	(1-5)	-	-	-	-
Cerastium fontanum	III	(1-3)	II	(1-2)	II	(1-2)
Lotus corniculatus	III	(1-5)	-	-	-	-
Ranunculus acris	III	(1-3)	IV	(1)	II	(1)
Conopodium majus	II	(1-3)	-	-	-	-
Euphrasia officinalis agg.	II	(1-4)	I	(1)	-	-
Luzula campestris	II	(1-3)	-	-	-	-
Veronica chamaedrys	II	(1-3)	-	-	-	-
Achillea millefolium	I	(3)	-	-	-	-
Bellis perennis	I	(1-2)	-	-	-	-
Botrychium lunaria	I	(1-2)	-	-	-	-
Campanula rotundifolia	I	(1)	-	-	-	-
Centaurea nigra	I	(1-5)	IV	(1-2)	I	(1)
Galium verum	I	(2)	-	-	-	-
Heracleum sphondylium	I	(1-4)	-	-	-	-
Lathyrus montanus	I	(1-3)	-	-	-	-
L. pratensis	I	(1-3)	-	-	-	-
Leontodon hispidus	I	(7)	II	(1)	-	-

Table 7.3 continued:

Species	PENNERLEY		EXPERIMENTAL TREATMENTS			
			Hay		Seed	
	a	b	a	b	a	b
Linum catharticum	I	(1-2)	-	-	-	-
Lolium perenne	I	(1-4)	-	-	-	-
Platanthera chlorantha	I	(1)	-	-	-	-
Potentilla erecta	I	(1-2)	-	-	-	-
Primula veris	I	(1-6)	-	-	-	-
Prunella vulgaris	I	(1-2)	I	(1)	-	-
Pteridium aquilinum	I	(4)	-	-	-	-
Rubus fruticosus agg.	I	(1)	-	-	-	-
Taraxacum spp.	I	(1)	-	-	I	(1)
Trifolium dubium	I	(1)	-	-	I	(1)
Vaccinium myrtillus	I	(2)	-	-	-	-
Vicia cracca	I	(1-2)	-	-	-	-
Viola lutea	I	(3)	-	-	-	-
V. riviniana	I	(1-3)	-	-	-	-
Agrostis gigantea	-	-	III	(1-4)	III	(1-2)
Bromus mollis	-	-	I	(1-2)	I	(1)
Cirsium vulgare	-	-	I	(1-2)	I	(1)
Epilobium ciliatum	-	-	III	(1)	III	(1)
Fraxinus excelsior	-	-	I	(1)	I	(1)
Juncus bufonius	-	-	I	(1)	-	-
Poa trivialis	-	-	V	(1-2)	V	(1-2)
Plantago major	-	-	-	-	I	(1)
Quercus robur	-	-	-	-	I	(1)
Raphanus raphanistrum	-	-	I	(2)	-	-
Ranunculus repens	-	-	V	(1-5)	V	(2-4)
Rumex crispus	-	-	-	-	I	(1-2)
R. obtusifolius	-	-	II	(1)	III	(1-5)
Senecio jacobea	-	-	I	(1)	-	-
Sonchus asper	-	-	I	(1)	I	(1)
Spergularia sp.	-	-	I	(1)	I	(1)
Trifolium sp.	-	-	-	-	I	(1)
Tripleurospermum inodorum	-	-	II	(1-2)	III	(1-2)
Ulex *sp.*	-	-	-	-	I	(1)
Vicia hirsuta	-	-	I	-	-	-

Summary	PENNERLEY	EXPERIMENTAL TREATMENTS	
		Hay	Seed
mean no. species/quadrat	18.6	15.6	9.9
total no. of stands	111	24	24
total no. of species	48	35	31

Table 7.4: Floristic table for plots in the experiment comparing hay strewing and purchased seed mixture in 1989.
a = frequency class, b = domin range.

Species	PENNERLEY		EXPERIMENTAL TREATMENTS			
			Hay		Seed	
	a	b	a	b	a	b
Agrostis capillaris	V	(2-8)	V	(4-5)	V	(2-3)
Anthoxanthum odoratum	V	(2-4)	V	(5)	I	(2)
Cynosurus cristatus	V	(1-5)	V	(1-3)	II	(1-3)
Dactylis glomerata	V	(1-5)	-	-	-	-
Festuca rubra	V	(5-9)	V	(4-5)	I	(2)
Holcus lanatus	V	(1-8)	V	(4-7)	V	(9-10)
Hypochoeris radicata	V	(1-4)	V	(3-5)	V	(1-4)
Leucanthemum vulgare	V	(1-6)	V	(4-5)	II	(1-2)
Plantago lanceolata	V	(2-7)	V	(5)	I	(1)
Ranunculus bulbosus	V	(1-4)	IV	(1-2)	-	-
Rhinanthus minor	V	(1-7)	V	(2-3)	-	-
Trifolium pratense	V	(1-6)	II	(2-3)	-	-
Briza media	IV	(1-4)	-	-	-	-
Hieracium pilosella	IV	(1-5)	I	(1)	-	-
Rumex acetosa	IV	(1-5)	V	(1-2)	I	(1)
Trifolium repens	IV	(1-5)	III	(2)	I	(2)
Trisetum flavescens	IV	(1-5)	III	(1)	-	-
Cerastium fontanum	III	(1-3)	V	(1-2)	-	-
Lotus corniculatus	III	(1-5)	-	-	-	-
Ranunculus acris	III	(1-3)	I	(1)	-	-
Conopodium majus	II	(1-3)	-	-	-	-
Euphrasia officinalis agg.	II	(1-4)	-	-	-	-
Luzula campestris	II	(1-3)	II	(1)	-	-
Veronica chamaedrys	II	(1-3)	-	-	-	-
Achillea millefolium	I	(3)	-	-	-	-
Bellis perennis	I	(1-2)	-	-	-	-
Botrychium lunaria	I	(1-2)	-	-	-	-
Campanula rotundifolia	I	(1)	-	-	-	-
Centaurea nigra	I	(1-5)	V	(2-3)	II	(1)
Galium verum	I	(2)	-	-	-	-
Heracleum sphondylium	I	(1-4)	-	-	-	-
Lathyrus montanus	I	(1-3)	-	-	-	-
L. pratensis	I	(1-3)	-	-	-	-
Leontodon hispidus	I	(7)	III	(2)	-	-

Table 7.4 continued:

Species	PENNERLEY		EXPERIMENTAL TREATMENTS			
			Hay		Seed	
	a	b	a	b	a	b
Linum catharticum	I	(1-2)	-	-	-	-
Lolium perenne	I	(1-4)	-	-	-	-
Platanthera chlorantha	I	(1)	-	-	-	-
Potentilla erecta	I	(1-2)	-	-	-	-
Primula veris	I	(1-6)	-	-	-	-
Prunella vulgaris	I	(1-2)	I	(2)	-	-
Pteridium aquilinum	I	(4)	-	-	-	-
Rubus fruticosus agg.	I	(1)	-	-	-	-
Taraxacum spp.	I	(1)	-	-	II	(1)
Trifolium dubium	I	(1)	-	-	I	(1)
Vaccinium myrtillus	I	(2)	-	-	-	-
Vicia cracca	I	(1-2)	-	-	-	-
Viola lutea	I	(3)	-	-	-	-
V. riviniana	I	(1-3)	-	-	-	-
Agrostis gigantea	-	-	I	(2)	-	-
Epilobium ciliatum	-	-	I	(1)	I	(1)
Holcus mollis	-	-	-	-	I	(2)
Poa trivialis	-	-	-	-	I	(1)
Ranunculus repens	-	-	V	(2-3)	V	(3-4)
Rumex crispus	-	-	-	-	II	(1)
R. obtusifolius	-	-	-	-	II	(2-4)

Summary	PENNERLEY	EXPERIMENTAL TREATMENTS	
		Hay	Seed
mean no. species/quadrat	18.6	16.4	7.3
total no. of stands	111	6	6
total no. of species	48	24	19

Table 7.5: Floristic table for plots in the experiment comparing hay strewing and purchased seed mixture in 1988 (Showing cutting treatment).
a = frequency class, b = domin range.

	PENNERLEY		EXPERIMENTAL PLOTS							
			Hay + cut		Hay - cut		Seed + cut		Seed - cut	
Species	a	b	a	b	a	b	a	b	a	b
Agrostis capillaris	V	(2-8)	IV	(1-3)	V	(1-3)	I	(2)	II	(2-3)
Anthoxanthum odoratum	V	(2-4)	V	(2-4)	V	(2-4)	-	-	-	-
Cynosurus cristatus	V	(1-5)	II	(1)	-	-	I	(1)	-	-
Dactylis glomerata	V	(1-5)	-	-	-	-	-	-	-	-
Festuca rubra	V	(5-9)	V	(2-5)	V	(2-4)	V	(1-2)	IV	(1-2)
Holcus lanatus	V	(1-8)	V	(4-9)	V	(6-9)	V	(9-10)	V	(9-10)
Hypochoeris radicata	V	(1-4)	V	(3-5)	V	(2-5)	V	(1-2)	III	(1-2)
Leucanthemum vulgare	V	(1-6)	V	(2-5)	V	(2-4)	III	(1)	II	(1)
Plantago lanceolata	V	(2-7)	V	(1-4)	V	(2-4)	I	(1)	-	-
Ranunculus bulbosus	V	(1-4)	IV	(1-2)	IV	(1-2)	-	-	-	-
Rhinanthus minor	V	(1-7)	V	(1-3)	V	(2-3)	-	-	-	-
Trifolium pratense	V	(1-6)	I	(1-2)	-	-	-	-	I	(2)
Briza media	IV	(1-4)	-	-	-	-	-	-	-	-
Hieracium pilosella	IV	(1-5)	I	(1)	I	(1)	-	-	-	-
Rumex acetosa	IV	(1-5)	I	(1)	II	(1-2)	IV	(1-2)	II	(1)
Trifolium repens	IV	(1-5)	II	(2)	III	(1-2)	II	(1)	III	(1-2)
Trisetum flavescens	IV	(1-5)	-	-	-	-	-	-	-	-
Cerastium fontanum	III	(1-3)	III	(1-2)	II	(1-2)	III	(1)	II	(1-2)
Lotus corniculatus	III	(1-5)	-	-	-	-	-	-	-	-
Ranunculus acris	III	(1-3)	IV	(1)	IV	(1)	II	(1)	II	(1)
Conopodium majus	II	(1-3)	-	-	-	-	-	-	-	-
Euphrasia officinalis agg.	II	(1-4)	I	(1)	-	-	-	-	-	-
Luzula campestris	II	(1-3)	-	-	-	-	-	-	-	-
Veronica chamaedrys	II	(1-3)	-	-	-	-	-	-	-	-
Achillea millefolium	I	(3)	-	-	-	-	-	-	-	-
Bellis perennis	I	(1-2)	-	-	-	-	-	-	-	-
Botrychium lunaria	I	(1-2)	-	-	-	-	-	-	-	-
Campanula rotundifolia	I	(1)	-	-	-	-	-	-	-	-
Centaurea nigra	I	(1-5)	V	(1-2)	IV	(1)	I	(1)	I	(1)
Galium verum	I	(2)	-	-	-	-	-	-	-	-
Heracleum sphondylium	I	(1-4)	-	-	-	-	-	-	-	-
Lathyrus montanus	I	(1-3)	-	-	-	-	-	-	-	-
L. pratensis	I	(1-3)	-	-	-	-	-	-	-	-
Leontodon hispidus	I	(7)	II	(1)	II	(1)	-	-	-	-

Table 7.5 continued:

Species	PENNERLEY a	PENNERLEY b	Hay + cut a	Hay + cut b	Hay - cut a	Hay - cut b	Seed + cut a	Seed + cut b	Seed - cut a	Seed - cut b
Linum catharticum	I	(1-2)	-	-	-	-	-	-	-	-
Lolium perenne	I	(1-4)	-	-	-	-	-	-	-	-
Platanthera chlorantha	I	(1)	-	-	-	-	-	-	-	-
Potentilla erecta	I	(1-2)	-	-	-	-	-	-	-	-
Primula veris	I	(1-6)	-	-	-	-	-	-	-	-
Prunella vulgaris	I	(1-2)	-	-	I	(1)	-	-	-	-
Pteridium aquilinum	I	(4)	-	-	-	-	-	-	-	-
Rubus fruticosus agg.	I	(1)	-	-	-	-	-	-	-	-
Taraxacum spp.	I	(1)	-	-	-	-	I	(1)	-	-
Trifolium dubium	I	(1)	-	-	-	-	II	(1)	-	-
Vaccinium myrtillus	I	(2)	-	-	-	-	-	-	-	-
Vicia cracca	I	(1-2)	-	-	-	-	-	-	-	-
Viola lutea	I	(3)	-	-	-	-	-	-	-	-
V. riviniana	I	(1-3)	-	-	-	-	-	-	-	-
Agrostis gigantea	-	-	III	(1-4)	III	(1-2)	IV	(1-2)	III	(1-2)
Bromus mollis	-	-	-	-	II	(1-2)	I	(1)	-	-
Cirsium vulgare	-	-	-	-	I	(1-2)	I	(1)	I	(1)
Epilobium ciliatum	-	-	IV	(1)	II	(1)	II	(1)	V	(1)
Fraxinus excelsior	-	-	-	-	I	(1)	I	(1)	I	(1)
Juncus bufonius	-	-	II	(1)	-	-	-	-	-	-
Poa trivialis	-	-	V	(1-2)	V	(1-2)	V	(2)	IV	(1-2)
Plantago major	-	-	-	-	-	-	II	(1)	I	(1)
Quercus robur	-	-	-	-	-	-	-	-	I	(1)
Raphanus raphanistrum	-	-	-	-	I	(2)	-	-	-	-
Ranunculus repens	-	-	V	(1-5)	V	(2-4)	V	(3-4)	V	(2-3)
Rumex crispus	-	-	-	-	-	-	I	(2)	II	(1)
R. obtusifolius	-	-	III	(1)	II	(1)	V	(1-5)	-	-
Senecio jacobea	-	-	-	-	I	(1)	-	-	-	-
Sonchus asper	-	-	-	-	I	(1)	II	(1)	I	(1)
Spergularia sp.	-	-	I	(1)	I	(1)	I	(1)	-	-
Trifolium sp.	-	-	-	-	-	-	-	-	I	(1)
Tripleurospermum inodorum	-	-	II	(1-2)	I	(1)	IV	(1-2)	III	(1-2)
Ulex sp.	-	-	-	-	-	-	I	(1)	-	-
Vicia hirsuta	-	-	I	(1)	-	-	-	-	-	-

Summary	PENNERLEY	EXPERIMENTAL PLOTS Hay + cut	Hay - cut	Seed + cut	Seed - cut
mean no. species/quadrat	18.6	15.8	15.4	11.3	8.5
total no. of stands	111	12	12	12	12
total no. of species	48	28	30	28	23

Table 7.6: Floristic table for plots in the experiment comparing hay strewing and purchased seed mixture in 1989 (showing cutting treatment).

a = frequency class, b = domin range

	PENNERLEY		EXPERIMENTAL PLOTS							
			Hay + cut		Hay - cut		Seed + cut		Seed - cut	
Species	a	b	a	b	a	b	a	b	a	b
Agrostis capillaris	V	(2-8)	V	(5)	V	(4-5)	V	(2)	V	(2-3)
Anthoxanthum odoratum	V	(2-4)	V	(5)	V	(5)	I	(2)	-	-
Cynosurus cristatus	V	(1-5)	V	(1-2)	V	(2-3)	I	(3)	I	(1)
Dactylis glomerata	V	(1-5)	-	-	-	-	-	-	-	-
Festuca rubra	V	(5-9)	V	(4-5)	V	(5)	-	-	I	(2)
Holcus lanatus	V	(1-8)	V	(4-7)	V	(4-5)	V	(10)	V	(9-10)
Hypochoeris radicata	V	(1-4)	V	(3-4)	V	(4-5)	II	(1-4)	V	(1-2)
Leucanthemum vulgare	V	(1-6)	V	(4-5)	V	(5)	I	(1)	I	(2)
Plantago lanceolata	V	(2-7)	V	(5)	V	(5)	I	(1)	-	-
Ranunculus bulbosus	V	(1-4)	III	(2)	III	(1)	-	-	-	-
Rhinanthus minor	V	(1-7)	V	(2-3)	V	(3)	-	-	-	-
Trifolium pratense	V	(1-6)	I	(3)	I	(2)	-	-	-	-
Briza media	IV	(1-4)	-	-	-	-	-	-	-	-
Hieracium pilosella	IV	(1-5)	-	-	I	(1)	-	-	-	-
Rumex acetosa	IV	(1-5)	III	(1-2)	V	(1-2)	I	(1)	-	-
Trifolium repens	IV	(1-5)	I	(2)	III	(2)	-	-	I	(2)
Trisetum flavescens	IV	(1-5)	III	(1)	I	(1)	-	-	-	-
Cerastium fontanum	III	(1-3)	V	(2)	V	(1-2)	-	-	-	-
Lotus corniculatus	III	(1-5)	-	-	-	-	-	-	-	-
Ranunculus acris	III	(1-3)	I	(1)	-	-	-	-	-	-
Conopodium majus	II	(1-3)	-	-	-	-	-	-	-	-
Euphrasia officinalis agg.	II	(1-4)	-	-	-	-	-	-	-	-
Luzula campestris	II	(1-3)	I	(1)	I	(1)	-	-	-	-
Veronica chamaedrys	II	(1-3)	-	-	-	-	-	-	-	-
Achillea millefolium	I	(3)	-	-	-	-	-	-	-	-
Bellis perennis	I	(1-2)	-	-	-	-	-	-	-	-
Botrychium lunaria	I	(1-2)	-	-	-	-	-	-	-	-
Campanula rotundifolia	I	(1)	-	-	-	-	-	-	-	-
Centaurea nigra	I	(1-5)	III	(2)	V	(2-3)	I	(1)	I	(1)
Galium verum	I	(2)	-	-	-	-	-	-	-	-
Heracleum sphondylium	I	(1-4)	-	-	-	-	-	-	-	-
Lathyrus montanus	I	(1-3)	-	-	-	-	-	-	-	-
L. pratensis	I	(1-3)	-	-	-	-	-	-	-	-
Leontodon hispidus	I	(7)	I	(2)	III	(2)	-	-	-	-

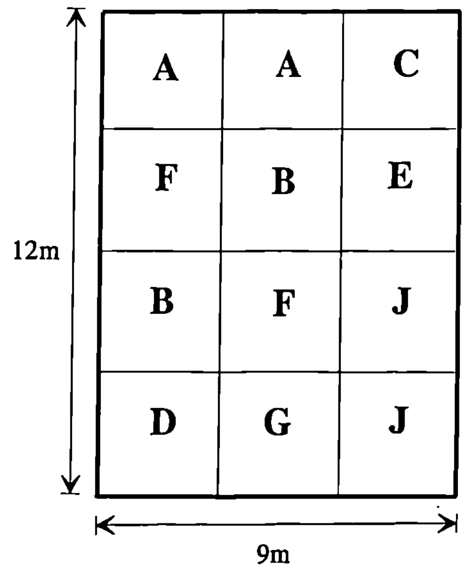
Table 7.6 continued:

Species	PENNERLEY		EXPERIMENTAL PLOTS							
			Hay + cut		Hay - cut		Seed + cut		Seed - cut	
	a	b	a	b	a	b	a	b	a	b
Linum catharticum	I	(1-2)	-	-	-	-	-	-	-	-
Lolium perenne	I	(1-4)	-	-	-	-	-	-	-	-
Platanthera chlorantha	I	(1)	-	-	-	-	-	-	-	-
Potentilla erecta	I	(1-2)	-	-	-	-	-	-	-	-
Primula veris	I	(1-6)	-	-	-	-	-	-	-	-
Prunella vulgaris	I	(1-2)	-	-	I	(2)	-	-	-	-
Pteridium aquilinum	I	(4)	-	-	-	-	-	-	-	-
Rubus fruticosus agg.	I	(1)	-	-	-	-	-	-	-	-
Taraxacum spp.	I	(1)	-	-	-	-	III	(1)	-	-
Trifolium dubium	I	(1)	-	-	-	-	I	(1)	-	-
Vaccinium myrtillus	I	(2)	-	-	-	-	-	-	-	-
Vicia cracca	I	(1-2)	-	-	-	-	-	-	-	-
Viola lutea	I	(3)	-	-	-	-	-	-	-	-
V. riviniana	I	(1-3)	-	-	-	-	-	-	-	-
Agrostis gigantea	-	-	I	(2)	I	(2)	-	-	-	-
Epilobium ciliatum	-	-	-	-	I	(1)	I	(1)	-	-
Holcus mollis	-	-	-	-	-	-	-	-	I	(2)
Poa trivialis	-	-	-	-	-	-	-	-	I	(1)
Ranunculus repens	-	-	V	(2)	V	(2-3)	V	(4)	V	(3-4)
Rumex crispus	-	-	-	-	-	-	III	(1)	-	-
R. obtusifolius	-	-	-	-	-	-	III	(2-4)	-	-

Summary	PENNERLEY	EXPERIMENTAL PLOTS			
		Hay + cut	Hay - cut	Seed + cut	Seed - cut
mean no. species/quadrat	18.6	15.7	17.0	8.3	6.3
total no. of stands	111	3	3	3	3
total no. of species	48	21	22	15	11

FIGURES

Figure 7.1: Plan of the Experimental Area at Compton Agricultural Unit, Wolverhampton, for the Hay Versus Seed Experiment Showing the Relative Positions of the Plots.



KEY

A Species-rich hay plus topping
B Species-rich hay no topping
C Commercial seed mix plus topping
D Commercial seed mix no topping

CHAPTER 8

The Use of Hay Strewing to Create a Damp Meadow

8.0 The Use of Hay Strewing to Create a Damp Meadow

8.1 Introduction

Previous chapters have considered meadow creation experiments using the hay strewing technique in which a single source of hay, Pennerley Meadows, has been used. It is possible that the moderate level of success achieved was as much a result of the type of hay used as the approach to site preparation, hay transport methods and management. In order to investigate the wider application of the hay strewing approach, alternative semi-natural grassland sites were found and the hay from these sites was used in attempts to recreate their plant communities. Several experiments were carried out in Wolverhampton, and two, undertaken as part of the present study, are described in this and the following chapter.

The donor grasslands from which hay was harvested and used in an attempt to replicate the plant communities present were mesotrophic but contrasted with Pennerley Meadows as they supported a species assemblage characteristic of damper soils.

This chapter describes an experiment in which the hay strewing approach was used in an attempt to create a damp meadow in Wolverhampton.

A donor site for the experiment was found on Catherton Common, an area dominated by acidic heathland on the slopes of Titterstone Clee in South Shropshire. Coal has been mined on the Common in the past and, as on the Stiperstones (Chapter 2), a few of the numerous miners cottages and smallholdings still have areas of unimproved grassland. One such smallholding, at Crumpsbrook (grid ref. SO 630781), has an area of particularly diverse damp meadowland that is now managed as a nature reserve by a private owner. The meadow at Crumpsbrook is listed as a Prime Site for Nature Conservation by the Shropshire Wildlife Trust and is also a SSSI.

The soils present at the Crumpsbrook reserve are surface water gleys (Burnham & Mackney, 1964) and overlie clay subsoil. Water therefore remains close to the surface as it drains from neighbouring hillside.

The meadow, measuring approximately 1.5 acres in extent, has an undocumented history but has been managed by hay cutting for many years. In recent years the aftermath growth has been grazed by donkeys but it remains unclear whether grazing formed part of the management prior to this.

There are no records of fertiliser use other than manuring resulting from the donkeys use of the meadow. It is probable, however, that lime has been used in the past. Although liming is not remembered by the present owner, the meadow soil has a mean pH of 5.2 which, although quite low, is likely to be higher than that of the surrounding *Calluna vulgaris* dominated heathland. It is also likely that the water passing through the site is base enriched as a result of the influence of the carboniferous limestone which underlies the coal measures on which the meadow and surrounding heathland sit.

The meadow sward is dominated by grasses such as *Anthoxanthum odoratum*, *Cynosurus cristatus*, *Agrostis capillaris* and *Festuca rubra* and has spring flora characterised by species such as *Primula veris*, *Luzula campestris* and *Cardamine pratense*. The margins of the meadow, which is bordered by mature trees and hedgerows, support a number of herb species more characteristic of woodlands such as *Hyacinthoides non-scripta*, *Anemone nemorosa* and *Viola riviniana*.

The summer flora of the meadow is characterised by a large number of species and includes *Polygala vulgaris*, *Ranunculus acris*, *Lotus corniculatus* and *Vicia cracca*. The hemi-parasites *Euphrasia officinalis agg.*, *Pedicularis sylvatica* and *Rhinanthus minor* are also present, although the last two species are currently infrequent in the meadow sward. The meadow also supports a late summer flora which is characterised by stands of *Succisa pratensis* and *Centaurea nigra*, with other species such as *Stachys officinalis* and *Campanula rotundifolia* locally abundant at that time of the year.

There are a number of uncommon or regionally rare species growing in the meadow including *Ophioglossum vulgatum*, *Botrychium lunaria*, *Carex pallescens*, *Listera ovata* and *Dactylorhiza fuchsii*.

A site was made available by Wolverhampton MBC at Valley Park School for the experiment. The school is situated approximately 2.5 miles from Wolverhampton town centre on the edge of a particularly densely populated area and bounded on two sides by housing and roads. Relatively open land lies on the other sides of the school grounds. The majority of the school grounds supported amenity grassland maintained on a regular gang-mowing regime with planted areas of shrubs and individual standard trees. One small area was left unmanaged as a 'wild area'.

The experimental site was in an area supporting amenity grassland which, before the school was built, had been the site of a factory. Following the demolition of the factory the ground had been levelled, capped with top soil and seeded. Large amounts of building rubble remained, generally over a foot below the surface, and together with a pan formed during the reclamation works, prevented the free drainage of water from the site. During winter, the site became damp as water draining from adjacent land accumulated there. By contrast the site was usually dry during the warmer months of the year, so much so that the soil often cracked during mid-summer.

As part of the experiment, different approaches to site preparation were also investigated and compared.

Growing crops as a method of reducing the levels of available plant nutrients has been discussed in Chapters 5 and 6. Maize has been used by Dutch workers to reduce the fertility of habitat creation sites (Londo, 1977). The use of maize was tested in small plots in the present study as part of the replicated cropping experiment described in Chapter 6. It was also used at Valley Park School.

Certain problems with the use of maize at Valley Park School could be envisaged. When grown in agricultural systems the crop requires a careful choice of site. It can be grown on a wide range of soil types but requires a good seedbed tilth and best results are obtained on deep, free working loams (MAFF, 1985). However, as the experimental site at Valley Park School had problems typical of those encountered at many urban sites, cropping with maize would be a test of the suitability of this crop for habitat creation in urban areas.

Another often mentioned method of lowering the levels of soil fertility involves the removal of the existing turf prior to seeding. This was investigated at Valley Park School where the amenity turf from part of the site was removed prior to seeding.

Turf removal prevents the nutrients that are incorporated within the existing vegetation from being returned to the soil during site preparation, and removes the top layer of topsoil and its incorporated nutrient pool. Soil organic matter, nitrogen and phosphorus are typically greatest in the surface layers (Marrs, in press) and turf removal would remove some of these instantly, whether they are in available forms or not.

The majority of seeds in soil are also present in surface layers and turf stripping will remove many of these. Therefore, turf removal or top-soil stripping may, in some circumstances, remove seeds which could be used as propagules for restoration work. Marrs (1985), for example, found the seeds of thirty one dicotyledons and ten grasses in the surface soils of an ex-heathland in Brekland. Putwain (1988) suggests that heathland soils stripped to a depth of 5cm will seed 1.5-2 times the area of the donor site.

However, on urban sites the surface seed bank may include persistent perennial weeds such as docks (*Rumex spp.*). The removal of the seed of such problematic species in stripped turf or top-soil would therefore be beneficial.

8.2 Methods

8.2.1 Site Preparation and Seeding

A rectangular area measuring 1250m^2 was delimited within the available area at Valley Park School in the early spring of 1987. The experimental area was divided into eight plots measuring 12.5m x 12.5m and on the 13 March 1987 four were sprayed with glyphosate to kill the existing vegetation. On 6 May 1987 the turf was removed from remaining four plots by staff of Wolverhampton Borough Council Parks Department using a mechanical turf stripper and turfing irons. The whole experimental area was ploughed and harrowed on 11 May 1987. Rubble brought to the surface by ploughing was removed from the site. Half of the site was then sowed with maize at a rate of 40-50kg/ha using a tractor drawn seed drill to give two replicates of the following four treatments as shown in Figure 8.1 (p. 228):

i) turf stripped only
ii) cropped with maize only
iii) turf stripped and cropped with maize
iv) control - turf retained and no cropping

The maize crop was allowed to grow, without weeding, until it was harvested in early August 1987. The experimental area was then rotovated to produce a fine seedbed and any surviving weeds were killed with a contact herbicide containing paraquat.

On 10 August the Crumpsbrook meadow was cut using an Allen scythe and a brush cutter; the access to the meadow being unsuitable for larger cutting equipment. The following day the hay was carried in bags and loaded onto to a lorry and then transported loose to the experimental area at Valley Park School. At the experimental site the hay was unloaded and spread evenly over each of the plots.

The strewn hay was left to dry and after several weeks raked into piles and removed from the site. During the drying period, the hay was turned by hand on several occasions.

The vegetation that established at Valley Park School was cut using a tractor mounted rotary mower during September 1988. The clippings were allowed to dry for several weeks and were subsequently removed from the site.

A large number of annual and perennial weeds germinated in the plots and it was necessary to kill dock species (*Rumex obtusifolius* and *R. crispus*) with spot treatments of glyphosate to prevent their persistence within the developing sward. This was done on several occasions during the spring of 1988. Although there was a danger that this treatment may have had an effect the overall results of the experiment, the docks were present throughout the created grassland sward and there appeared to be no correlation between the presence of docks and the particular treatments used. In view of the large number of docks which developed and the suppressive effects they would have had on the developing meadow sward, it seemed appropriate to treat them in this way.

8.2.2 Survey Methods

The vegetation at the Crumpsbrook meadow was surveyed in early June 1988. A series of five transect lines were run across the site. An estimate was made of the percentage cover of the species present within a 1m x 1m quadrat positioned at five meter intervals along each transect line. A total of 54 quadrats were recorded.

Sward establishment was slow at the experimental site much of which remained devoid of vegetation cover during 1988. Surveys of the created meadow were therefore postponed until late June 1989, the second year after its creation. Ten random 1m x 1m quadrats were recorded in each plot. As before, the percentage cover of species present within each quadrat was recorded.

Ten random soil samples were also collected from each of the experimental plots using an auger with a core diameter of 7cm. Samples were taken to a depth of approximately 12cm. The ten samples from each plot were combined and thoroughly mixed before being analysed.

Random soil samples were also collected at the donor meadow using the same auger. These samples were also combined and thoroughly mixed before being analysed.

Parameters measured were soil pH, nitrogen as nitrate and ammonium, available phosphorus, available potassium and loss on ignition. Standard analytical methods were used for the analyses (Ministry of Agriculture, Fisheries and Food, 1986).

8.2.3 Analytical Methods

TWINSPAN was used during the analysis of the vegetation data obtained during the survey of the experimental plots at Valley Park School. This polythetic, divisive classification technique has been described in Chapter 7.

8.3 Results

8.3.1 Survey of Donor Meadow

The survey of the Crumpsbrook Meadow indicated that the sward was indeed diverse, as described in the introduction to this chapter. A total of 74 species were recorded (Table 8.1: p. 212) with a mean of 20.4 species recorded per quadrat. Both these figures are higher than those recorded at Pennerley Meadows, the donor meadow for other experiments undertaken in Wolverhampton. However, the high frequency, 'constant' species (frequency classes IV and V) were, as at Pennerley Meadows, restricted to a small number of common grassland species.

Table 8.1 (p. 212) indicates that there was a degree of heterogeneity in the Crumpsbrook Meadow sward. Several species recorded at lower frequency levels had a large domin range with high maximum domin scores (eg. *Dactylis glomerata*, *Lotus corniculatus*, *Succisa pratensis*, *Alopecurus pratensis* and *Poa trivialis*) indicating a local distribution in the sward. Variations in the donor sward were apparent with possibly nutrient enriched areas supporting a coarser and less diverse vegetation present around some of the margins. These areas were avoided during the hay cutting and loading operation.

A large number of species were recorded in the lowest frequency class (I). These were uncommon or rare in the sward; many were only recorded in one quadrat. Their transference to the created meadow may therefore be regarded as a bonus rather than a measure of success.

Although the constant species are all commonly present in many types of mesotrophic grassland and not necessarily indicative of damp soil conditions, a number of the species recorded at lower frequencies give an indication of the moist conditions present at Crumpsbrook. The local abundance of *Succisa pratensis*, a species strongly associated with continuously moist habitats, is perhaps the best visual indicator of the moderately damp conditions present, although the high frequency of *Ranunculus repens* and presence of *Cardamine pratense*, *Lotus uliginosus* and *Juncus conglomeratus* are a further indication.

Many of the species present are not typically found on damp soils and some are on the whole absent from such substrates (eg. *Hieracium pilosella, Polygala vulgaris*). Their presence is a further indication of heterogeneity in the Crumpsbrook meadow sward with pockets of drier, perhaps base enriched soil.

Direct comparison with the NVC mesotrophic grassland communities (Table 8.2: p. 214) indicates that the Crumpsbrook meadow would appear to have the closest affinity with the MG5 *Cynosurus cristatus-Centaurea nigra* community, as does Pennerley Meadows (Chapter 2). It also seems to be closest to the *Lathyrus pratensis* sub-community of this classification but with characteristics of all three sub-communities.

The main discrepancies between the donor sward and a typical MG5 grasslands include the greater frequency of *Ranunculus repens* and *Succisa pratensis* and the presence and local abundance of *Lotus uliginosus*; a result of the more moist conditions there than in most grasslands of this community type. In addition to the presence of species associated with more moist soils, the lower frequencies of plants such as *Leucanthemum vulgare* and *Rhinanthus minor* and higher frequencies of *Centaurea nigra* and others at Crumpsbrook when compared to Pennerley Meadows results in these two donor sites supporting what visually appears to be different vegetation despite the similarities in terms of their NVC classification.

Using the same approach adopted before, the constant species and their associated mean % cover values provide a model against which the created meadow at Valley Park School can be compared (Table 8.3: p. 216 and Figure 8.2: p. 229).

8.3.2 Survey of the Created Meadow

As indicated above, the establishment of the created meadow at Valley Park School was slow. Several of the meadow species introduced as seed in the hay from the donor meadow germinated during Autumn 1987 and Spring 1988 but throughout 1988 the created meadow sward remained open, with much bare ground, and species diversity was low.

The specific reasons for the slow establishment of the Valley Park School meadow remain unclear. Meadows created using hay from Pennerley Meadows tend to develop a closed sward more quickly with many of the introduced species becoming established in the first year. The experimental area at Valley Park School was, however, wetter than any on which meadows created using hay from Pennerley Meadow had been attempted. This coupled with the particularly wet winter of 1987/88, means that germination and establishment of meadow species at the site may have been inhibited by water-logging.

Other factors may also have effected the establishment success in the first year. These include the relatively harsh soil conditions at the experimental site (see section 8.1), disturbance due to unauthorised use of the site by children from the school and heavy competition from perennial weeds such as *Rumex obtusifolius* and *R. crispus*, which developed so densely in places that spot treatments of herbicide were necessary.

R. obtusifolius, which was the most abundant of the docks to develop at the experimental site, may have been introduced as seed with the hay. However, this species was only present in the donor sward at low frequencies and was generally restricted to areas of the meadow margins which were avoided during the hay cut. Docks were present on and adjacent to the experimental area prior to site preparation, and the most likely reason for their abundance is the germination of its persistent seed (Cavers & Harper, 1964) released from the soil seed bank at the site by the cultivation used during site preparation. Furthermore, docks have the ability to regenerate from pieces of underground stem and root fragments (Cavers & Harper, 1964), and the ploughing and rotovation used during site preparation could have distributed many such fragments throughout the experimental substrate.

The broad, spreading leaves of *R. obtusifolius* covered a high percentage of the experimental plots and it is likely that they did prevent the germination and establishment of introduced meadow species.

By 1989 a relatively closed sward had become established. Although docks were still present, their abundance had been reduced by the spot herbicide treatments. Furthermore, the site appeared to be more freely draining and it seems likely that cultivation used during site preparation broke the pan present in the soil. This was probably beneficial in terms of seed germination, meaning that, except during very wet winters (eg. 1987/88), the site remains unwaterlogged. It also means, however, that the site will tend to dry out more quickly and the drying and cracking to which it is prone may be a more frequent and protracted event. This would not suit many of the species associated with more moist conditions present in the donor meadow sward.

During the June 1989 survey of the created meadow, a total of 60 species were recorded with a high mean number of species per quadrat (21.0) (Table 8.4: p. 217). Many of these species were weeds, also taking advantage of the soil disturbance resulting from site preparation as did the docks. Most of these species had not been introduced with the hay from Crumpsbrook meadow and were probably either present in the seed bank or introduced to the site as wind borne seed from neighbouring areas.

Despite the high number of weeds, many of the species recorded during the survey of the donor meadow were also recorded at Valley Park School (38 in total although *Rumex obtusifolius* was one of these and this has been discussed above). All of the more frequent species at Crumpsbrook meadow (frequency class III and higher), with the sole exception of *Luzula campestris*, were recorded at comparable levels of frequency in the created meadow. Domin ranges for most of the introduced species were also comparable, although many of the more abundant species in the donor meadow, indicated by a high maximum domin value, had not yet achieved the same level of abundance in the created meadow.

Of the less frequent species in the donor sward, a moderate number became established at Valley Park School although, as may be expected, none of the species associated with old grasslands such as *Ophioglossum vulgatum*, *Botrychium lunaria*, *Alchemilla vestita*, *Dactylorhiza fuchsii* or the sedges (*Carex* spp.) were noted.

Table 8.6 (p. 221) and Figure 8.3 (p.230) compare the constant species (frequency classes IV & V) in the Crumpsbrook Meadow in the donor and created meadows in terms of their recorded mean % cover. Although there are noticeable differences between the two sites for a number of species (*Agrostis capillaris*, *Festuca rubra*, *Holcus lanatus* and *Trifolium pratense*), and the cover values in the created sward are generally lower than those in the donor meadow, the relative proportions of most species are roughly comparable in both. The creation of the meadow may therefore be considered to be moderately successful in this respect.

The cover of both *Agrostis capillaris* and *Festuca rubra*, which are the most abundant species at the donor site and form the basic vegetation matrix of the meadow, is lower at the created meadow. This has been noted in other attempts at meadow creation in Wolverhampton (Chapter 3) and is perhaps not unexpected considering the meadow at Valley Park School was only in its second season at the time of the survey. Both species are characteristic of established grasslands and although *A. capillaris* is an effective colonist of artificial habitats (Grime *et al*, 1988), more competitive species such as *Holcus lanatus* usually gain the advantage in the early years of created meadows.

However, the cover value of *H. lanatus* in the created sward at Valley Park School was, at the time of the survey, only slightly higher than its equivalent value in the donor sward. As both *A. capillaris* and *F. rubra* have been successfully introduced to the created sward, and are present at high levels of frequency, the maintenance of an appropriate management regime should encourage tillering and their vegetative spread throughout the meadow, and levels of cover approximating to those recorded at the donor sward may be expected to develop.

The high levels of cover recorded for *Trifolium pratense* (and *T. repens* - see Table 8.4: p. 217) is of some concern. Nitrogen-fixing legumes often reach high levels of abundance on recently cleared land where nitrogen is limiting but other macro-nutrients are present. Other workers have noted the invasion of large amounts of clover in some created grasslands (Ash *et al*, 1992) and this was also noted at Bushbury Hill (Chapter 4). In some circumstances such species can out-compete other introduced species and lower the overall sward diversity.

Legumes also increase the fertility of soils in terms of nitrogen availability. They are often recommended for use during reclamation schemes on infertile or otherwise difficult soils for this reason (Bradshaw & Chadwick, 1980; Dancer *et al*, 1977) but this is usually an undesirable effect in meadow creation experiments.

Ash *et al* (1992) suggest that it is difficult to control clovers by herbicide treatments as was done for the invasive docks at Valley Park School. It may be that appropriate management and the consequential establishment and spread of other species will keep levels of these species in check but there seems to be little discussion of this in the literature.

Overall, a good proportion of the donor meadow species appear to have become established. The created sward did not, however, have the visual appearance or appeal of the meadow at Crumpsbrook. The sward was coarser, the grasses and larger forb species such as *Centaurea nigra* and *Rumex acetosa*, appearing more vigorous at the created meadow and attaining a greater height. The number of flowering stems of all species, grasses and forbs alike, also greatly exceeded that at the donor site.

The increased flowering may be expected at a new site where species are becoming established from seed and is typically the case in created meadows in the first year after establishment. There has been little time for vegetative development and each species strives for a competitive advantage by increasing flower and seed production. Provided a good range of species become established from the initial seeding, the introduction of an appropriate management regime would encourage greater vegetative growth as each plant exploits its niche within the meadow. The meadow would begin to 'settle down' and flowering reduced to more normal levels.

The increased height and vigour of certain species noted in the created meadow is perhaps of more concern as it may indicate elevated levels of soil fertility. Mean soil analysis results for both the donor and created meadows are presented in Table 8.5 (p. 220). Although levels of the more mobile nitrate and ammonium are low, the Valley Park soils are significantly richer than those of Crumpsbrook in terms of available potassium and particularly available phosphorus.

As explained in Chapter 6, elevated levels of phosphorus, which is relatively immobile in soils and therefore difficult to remove by cropping, are common in urban soils. The phosphorus levels recorded at Valley Park School fall within what Ash *et al* (1992) classify as infertile soils although they do fall within the range noted by Bradshaw and Chadwick (1980) for various productive British soils. Despite this apparent contradiction, the phosphorus levels recorded in the Valley Park School meadow are significantly higher than those measured at Crumpsbrook and may well be the reason for the abundance of legumes (*Trifolium pratense* and *T. repens*) in the created sward.

The high levels of abundance of these nitrogen fixing species may well raise soil fertility in the long-term and result in the ultimate deterioration of the sward and a decline in species diversity. Ash *et al* (1992) suggest that there is evidence to indicate that on areas where clover has been abundant soon after sowing, it naturally declines after 5-7 years. This may be because the soil nitrogen levels have built up to such an extent as a result of fixation by these species that they are eradicated by competition from other species. Natural fluctuations of these species have also been noted (Trueman, pers. comm.), and it seems that periodic high levels of abundance in spring and summer tend to correspond with a harsh winter.

The created meadow sward was also different in appearance from the meadow at Crumpsbrook due to the absence or lower frequency of some species which are visually characteristic of the donor sward. *Succisa pratensis* in particular is locally abundant in the donor meadow and forms colourful and appealing patches in late summer. Large quantities of seed of this species were present in the hay from the donor site that was spread at Valley Park School. However, although *S. pratensis* was introduced to the new meadow, it was not present at the same levels of frequency or local abundance as noted at the donor.

As suggested above, *S. pratensis* is a species characteristic of moist soils and its restricted establishment in the created sward may be an indication of inappropriate soil moisture levels there. This would also account for the absence in the created sward of other donor meadow species indicative of damper soils such as *Lotus uliginosus* and *Cardamine pratense*.

Grime *et al* (1988) suggest that *S. pratensis* attains its maximum frequency in the pH range 5.5-6.5 and they had no records for the species from sites with soil pH outside the range 3.5-7.5. The mean pH at Valley Park School was 7.1, which is therefore approaching the top end of the range for *S. pratensis* and may have been limiting to its establishment.

Grime *et al* (1988) also suggest that *S. pratensis* shows a clear association with habitats having little or no bare soil and its distribution is centred on vegetation associated with undisturbed conditions. The Valley Park School meadow was, at the time of the survey, new, relatively disturbed and open and this coupled with limiting soil pH and moisture conditions may account for the limited amounts of *S. pratensis* despite the large quantities of seed imported.

8.3.3 Performance of the Pre-treatments

As may have been expected on a site with such unsuitable soil conditions, the establishment of the maize crop was poor. This failure may also have been a result of the wet weather experienced during the early summer of 1987 and the loss of seed to pigeons feeding on the site. The crop distribution was patchy within the plots and the plants that established failed to develop as quickly as is normal.

The maximum height achieved by the time the maize was harvested was approximately 45cm. Early August is, however, very early for the harvest of maize, the dry matter yield of which can almost double between late July and mid September (Ministry of Agriculture, Fisheries and Food, 1985). Furthermore, weed competition during early growth of maize can have a serious effect on yields (MAFF, 1985) and it was impractical to attempt to control the weeds that established alongside the crop in the experimental plots.

When compared to the control plots, the cropping treatment had little effect on the levels of the major plant nutrients measured during the soil analysis (Table 8.7: p. 222). Slightly lower levels of phosphorus and potassium were recorded but analysis of variance indicated that these differences were not significant.

Similarly, the turf stripping treatment appeared to have little effect on the levels of macro-nutrients in the soils of the experimental plots. Again, slightly lower levels of phosphorus and potassium were recorded compared to the control plots, but these differences were not significant.

The soil in the plots in which turf stripping and cropping treatments were combined also had lower levels of available phosphorus and potassium than the control plots. In the case of potassium, analysis of variance indicated that this was a significant difference ($p < 0.05$). However the reduction was small and the levels recorded were still high relative to the donor site.

The mean results of the botanical survey for the different treatments are presented in Table 8.8 (p. 223). It is clear that there was very little difference between the four treatments in terms of the species present in the experimental plots. All had equivalent total numbers of species and mean numbers of species per quadrat and the different pre-treatments used appeared to have had no beneficial effect in terms of the establishment of particular meadow species.

Furthermore, weed species were present at similar frequencies and levels of abundance in all plots. The turf stripping therefore appears to have had little success at preventing weed colonisation despite the removal of seed in the surface layers of the soil.

Table 8.9 (p. 226) and Figure 8.4 (p. 231) show that the high frequency, constant species of the donor meadow had nearly identical cover values in the different experimental plots.

TWINSPAN failed to make any distinction between the experimental treatments on the basis of species composition. Divisions made by the analysis were based on variations in species between different quadrats which are not easily explained.

8.4 Discussion

Due to the limited information in the literature about the use of the hay strewing to create new meadows (see Chapter 1) and the lack of unreported practical application of the technique (Jones, 1990), is not possible to make comparisons between the experiment described here with other work in which different sources of hay have been used. Furthermore, much of the work undertaken using seed mixtures has involved the use of a limited range of species which generally include those characteristic of dry grassland communities. Few investigations appear to have been made into techniques for recreating damp grassland communities.

Although the experiment at Valley Park School may have been considered successful in terms of the numbers of species, particularly constant species, introduced from the donor site, the restricted introduction of species indicative of damp soils suggest that the creation of damp meadows is more problematic than the creation of dry meadows.

The reproduction of complex hydrological regimes is bound to be fraught with difficulties. If conditions which are too damp are produced, a marsh rather than a meadow will develop and the germination of many species will be inhibited. The Valley Park School meadow was probably slow to establish for these reasons. If conditions are produced which are too dry, many of the desired species will fail to establish even if germination is successful.

The pattern of water flow through a site is difficult to predict or control, let alone reproduce. At Crumpsbrook the water was noted to held at the surface due to underlying clay as it passed through the site. Furthermore the moisture conditions were not uniform throughout the donor site, localised patches remaining dry enough to support species which would not be able to tolerate damp conditions. At Valley Park School water did not move through the site but collected there as it drained from adjacent land due to the low-lying position of the site and the rubble and soil pan present. Under such circumstances it is probably sensible to only expect a limited level of success in terms of introducing species from the donor site indicative of soil moisture.

Even if hydrological regimes at donor and experimental sites are roughly equivalent, the chemical properties of the water are important to the success of meadow creation. It is unlikely that these properties can be manipulated without great expense.

Worthington and Helliwell (1987) describe attempts to translocate 2500m^2 of moist grassland and 1500m^2 of marsh vegetation, along with 350m^2 of dry grassland to a new site. They indicate that the overall level of floristic diversity and the general appearance of the vegetation were similar before and after transference. The value of drawing parallels between Worthington & Helliwells work and the experiments described in this and the following chapter is limited, as they were able to remove the whole soil profile from the donor site and replace it directly on a new site which lay only 400m away. However, they acknowledge that even using this approach, success will only be achieved if conditions of soil drainage are similar to those of the donor site.

It may be concluded from the failure of maize that the use of this crop for the purpose of reducing soil fertility is inappropriate for habitat creation unless carried out on a suitable substrate, with careful management of weeds and seed predators, and the crop is allowed to grow to maturity thus postponing meadow seeding until the following season.

As there was a slight indication that growing maize may have reduced the soil levels of some macro-nutrients during the Valley Park School experiment, more successful cropping with this species, particularly in combination with another treatment such as turf stripping, could potentially have a beneficial effect during habitat creation.

Turf stripping alone also had little effect during the experiment on either soil fertility in terms of macro-nutrients or the botanical composition of the created sward. Turf stripping only removes the surface layers of the top soil and removal of all of the topsoil may be necessary before beneficial effects are observed. On reclaimed urban sites such as that at Valley Park School this may be particularly problematic as the top soil has generally been imported and covers difficult, possibly phyto-toxic substrates and not infertile sub-soils. At Valley Park School building rubble and other materials are covered by the imported top-soil and these would not form a suitable seed bed material. At Bushbury Hill (Chapter 4), the original amenity grassland had been established over imported soil covering the clay cap of a domestic refuse tip. Removal of the top-soil at this site would also have left an unsuitable substrate for plant establishment.

Another problem which may occur as a result of topsoil removal is the lowering of the land level below the winter water table. This problem was encountered during attempts to use strewn hay to reproduce a damp pasture community in Wolverhampton and this is discussed in the next chapter.

TABLES

Table 8.1: Floristic Table for Crumpsbrook Meadow (1988)

a = frequency class b = domin range.

	Crumpsbrook	
species	a	b
Agrostis capillaris	V	(2-7)
Anthoxanthum odoratum	V	(2-6)
Centaurea nigra	V	(1-6)
Cerastium fontanum	V	(1-3)
Cynosurus cristatus	V	(2-5)
Festuca rubra	V	(2-8)
Holcus lanatus	V	(1-8)
Plantago lanceolata	V	(1-5)
Ranunculus acris	V	(1-6)
Rumex acetosa	V	(1-5)
Hypochoeris radicata	IV	(1-5)
Ranunculus repens	IV	(1-7)
Trifolium pratense	IV	(2-5)
Dactylis glomerata	III	(2-8)
Leontodon autumnalis	III	(1-3)
Lotus corniculatus	III	(2-8)
Luzula campestris	III	(1-3)
Prunella vulgaris	III	(1-4)
Succisa pratensis	III	(1-6)
Achillea millefolium	II	(1-4)
Alopecurus pratensis	II	(2-9)
Bellis perennis	II	(1-3)
Briza media	II	(1-3)
Conopodium majus	II	(1-3)
Lolium perenne	II	(2-4)
Lotus uliginosus	II	(1-6)
Poa trivialis	II	(2-9)
Potentilla erecta	II	(1-4)
Taraxacum spp.	II	(1-4)
Trifolium repens	II	(2-4)

Table 8.1 continued

species	Crumpsbrook a	Crumpsbrook b
Agrostis stolonifera	I	(2)
Ajuga reptans	I	(1-2)
Alchemilla vestita	I	(1-5)
Anemone nemorosa	I	(2)
Arrhenatherum elatius	I	(2)
Betonica officinalis	I	(2)
Botrychium lunaria	I	(1)
Bromus hordeaceus	I	(1-2)
Campanula rotundifolia	I	(2-4)
Cardamine pratense	I	(1-2)
Carex caryophyllea	I	(2)
C. flacca	I	(1-2)
C. hirta	I	(1)
Dactylorhiza fuchsii	I	(1-3)
Euphrasia officinalis agg.	I	(1-4)
Festuca pratensis	I	(1-4)
Heracleum sphondylium	I	(4)
Hieracium pilosella	I	(1-2)
Hyacinthoides non-scripta	I	(2)
Juncus bufonius	I	(1)
J. conglomeratus	I	(2)
Lathyrus montanus	I	(2)
L. pratensis	I	(2-3)
Leontodon hispidus	I	(1-4)
Leucanthemum vulgare	I	(1-3)
Ophioglossum vulgatum	I	(2)
Pedicularis sylvatica	I	(1-3)
Polygala vulgaris	I	(1-3)
Potentilla reptans	I	(1-2)
Primula veris	I	(1-2)
Quercus sp.	I	(1)
Ranunculus bulbosus	I	(1-3)
Rhinanthus minor	I	(2-3)
Rumex obtusifolius	I	(4)
Senecio sp.	I	(1-3)
Stellaria graminea	I	(2-3)
Trifolium medium	I	(1)
Trisetum flavescens	I	(2)
Veronica chamaedrys	I	(2-4)
V. officinalis	I	(1-2)
V. serpyllifolia	I	(1-2)
Vicia cracca	I	(2-3)
V. sepium	I	(4)
Viola riviniana	I	(1)

Summary	Crumpsbrook
mean no. species/quadrat	20.4
total no. of stands	54
total no. of species	74

Table 8.2: Floristic Table for Crumpsbrook Meadow (1988) and a Typical MG5 Grassland

a = frequency class b = domin range c = typical frequency in MG5 grasslands d = typical domin range in MG5 grasslands.

species	a	b	c	d
Agrostis capillaris	V	(2-7)	IV	(1-8)
Anthoxanthum odoratum	V	(2-6)	IV	(1-8)
Centaurea nigra	V	(1-6)	IV	(1-5)
Cerastium fontanum	V	(1-3)	II	(1-3)
Cynosurus cristatus	V	(2-5)	V	(1-8)
Festuca rubra	V	(2-8)	V	(1-8)
Holcus lanatus	V	(1-8)	IV	(1-6)
Plantago lanceolata	V	(1-5)	V	(1-7)
Ranunculus acris	V	(1-6)	III	(1-4)
Rumex acetosa	V	(1-5)	III	(1-4)
Hypochoeris radicata	IV	(1-5)	III	(1-5)
Ranunculus repens	IV	(1-7)	I	(1-7)
Trifolium pratense	IV	(2-5)	IV	(1-5)
Dactylis glomerata	III	(2-8)	IV	(1-7)
Leontodon autumnalis	III	(1-3)	III	(1-5)
Lotus corniculatus	III	(2-8)	V	(1-7)
Luzula campestris	III	(1-3)	III	(1-6)
Prunella vulgaris	III	(1-4)	III	(1-4)
Succisa pratensis	III	(1-6)	I	(1-5)
Achillea millefolium	II	(1-4)	III	(1-6)
Alopecurus pratensis	II	(2-9)	I	(1-6)
Bellis perennis	II	(1-3)	II	(1-7)
Briza media	II	(1-3)	II	(1-6)
Conopodium majus	II	(1-3)	I	(1-5)
Lolium perenne	II	(2-4)	III	(1-8)
Lotus uliginosus	II	(1-6)		
Poa trivialis	II	(2-9)	II	(1-8)
Potentilla erecta	II	(1-4)	I	(1-4)
Taraxacum spp.	II	(1-4)	III	(1-4)
Trifolium repens	II	(2-4)	IV	(1-9)

Table 8.2 continued

species	a	b	c	d
Agrostis stolonifera	I	(2)	I	(1-7)
Ajuga reptans	I	(1-2)		
Alchemilla vestita	I	(1-5)	I	(1-3)
Anemone nemorosa	I	(2)		
Arrhenatherum elatius	I	(2)	II	(1-7)
Betonica officinalis	I	(2)	I	(1-5)
Botrychium lunaria	I	(1)		
Bromus hordeaceus	I	(1-2)	I	(1-6)
Campanula rotundifolia	I	(2-4)		
Cardamine pratense	I	(1-2)	I	(1-3)
Carex caryophyllea	I	(2)	I	(1-4)
C. flacca	I	(1-2)	I	(1-4)
C. hirta	I	(1)		
Dactylorhiza fuchsii	I	(1-3)		
Euphrasia officinalis agg.	I	(1-4)		
Festuca pratensis	I	(1-4)	II	(1-5)
Heracleum sphondylium	I	(4)	II	(1-5)
Hieracium pilosella	I	(1-2)		
Hyacinthoides non-scripta	I	(2)		
Juncus bufonius	I	(1)		
J. conglomeratus	I	(2)		
Lathyrus montanus	I	(2)		
L. pratensis	I	(2-3)	II	(1-5)
Leontodon hispidus	I	(1-4)	II	(1-6)
Leucanthemum vulgare	I	(1-3)	II	(1-3)
Ophioglossum vulgatum	I	(2)	I	(1-5)
Pedicularis sylvatica	I	(1-3)		
Polygala vulgaris	I	(1-3)		
Potentilla reptans	I	(1-2)	I	(1-6)
Primula veris	I	(1-2)	II	(1-4)
Quercus sp.	I	(1)		
Ranunculus bulbosus	I	(1-3)	III	(1-7)
Rhinanthus minor	I	(2-3)	II	(1-5)
Rumex obtusifolius	I	(4)		
Senecio sp.	I	(1-3)		
Stellaria graminea	I	(2-3)		
Trifolium medium	I	(1)		
Trisetum flavescens	I	(2)	III	(1-6)
Veronica chamaedrys	I	(2-4)	II	(1-4)
V. officinalis	I	(1-2)		
V. serpyllifolia	I	(1-2)		
Vicia cracca	I	(2-3)	I	(1-4)
V. sepium	I	(4)		
Viola riviniana	I	(1)		

Table 8.3: Frequency and Abundance of 'Constant Species' at Crumpsbrook Meadow (1988)

a = frequency class, b = domin range, c mean % cover

	Crumpsbrook		
species	a	b	c
Agrostis capillaris	V	(2-7)	25.80
Anthoxanthum odoratum	V	(2-6)	7.13
Centaurea nigra	V	(1-6)	6.31
Cerastium fontanum	V	(1-3)	1.72
Cynosurus cristatus	V	(2-5)	3.41
Festuca rubra	V	(2-8)	30.93
Holcus lanatus	V	(1-8)	11.67
Plantago lanceolata	V	(1-5)	8.54
Ranunculus acris	V	(1-6)	5.69
Rumex acetosa	V	(1-5)	5.04
Hypochoeris radicata	IV	(1-5)	2.63
Ranunculus repens	IV	(1-7)	3.76
Trifolium pratense	IV	(2-5)	3.61

Table 8.4: Floristic Table for Crumpsbrook Meadow (1988) and Valley Park School Meadow (1989).

a = frequency class b = domin range.

species	Crumpsbrook a	Crumpsbrook b	Valley Park School a	Valley Park School b
Agrostis capillaris	V	(2-7)	V	(4-7)
Anthoxanthum odoratum	V	(2-6)	V	(4-5)
Centaurea nigra	V	(1-6)	V	(2-5)
Cerastium fontanum	V	(1-3)	V	(1-3)
Cynosurus cristatus	V	(2-5)	V	(2-5)
Festuca rubra	V	(2-8)	V	(2-5)
Holcus lanatus	V	(1-8)	V	(4-5)
Plantago lanceolata	V	(1-5)	V	(2-5)
Ranunculus acris	V	(1-6)	V	(1-3)
Rumex acetosa	V	(1-5)	V	(1-3)
Hypochoeris radicata	IV	(1-5)	III	(1-3)
Ranunculus repens	IV	(1-7)	III	(1-3)
Trifolium pratense	IV	(2-5)	V	(4-7)
Dactylis glomerata	III	(2-8)	III	(1-5)
Leontodon autumnalis	III	(1-3)	IV	(1-4)
Lotus corniculatus	III	(2-8)	II	(1-4)
Luzula campestris	III	(1-3)		
Prunella vulgaris	III	(1-4)	IV	(1-3)
Succisa pratensis	III	(1-6)	II	(1-4)
Achillea millefolium	II	(1-4)		
Alopecurus pratensis	II	(2-9)	I	(1-5)
Bellis perennis	II	(1-3)	I	(1-2)
Briza media	II	(1-3)		
Conopodium majus	II	(1-3)		
Lolium perenne	II	(2-4)	I	(1-4)
L. uliginosus	II	(1-6)		
P. trivialis	II	(2-9)	V	(1-3)
Potentilla erecta	II	(1-4)	I	(1)
Taraxacum spp.	II	(1-4)	IV	(1-4)
T. repens	II	(2-4)	V	(2-5)

Table 8.4 continued

species	Crumpsbrook a	Crumpsbrook b	Valley Park School a	Valley Park School b
Agrostis stolonifera	I	(2)	I	(2-4)
Ajuga reptans	I	(1-2)		
Alchemilla vestita	I	(1-5)		
Anemone nemorosa	I	(2)		
Arrhenatherum elatius	I	(2)		
Betonica officinalis	I	(2)		
Botrychium lunaria	I	(1)		
Bromus hordeaceus	I	(1-2)	I	(1-3)
Campanula rotundifolia	I	(2-4)		
Cardamine pratense	I	(1-2)		
Carex caryophyllea	I	(2)		
C. flacca	I	(1-2)		
C. hirta	I	(1)		
Dactylorhiza fuchsii	I	(1-3)		
Euphrasia officinalis agg.	I	(1-4)	I	(1-2)
Festuca pratensis	I	(1-4)	II	(1-4)
Heracleum sphondylium	I	(4)		
Hieracium pilosella	I	(1-2)		
Hyacinthoides non-scripta	I	(2)		
Juncus bufonius	I	(1)		
J. conglomeratus	I	(2)		
Lathyrus montanus	I	(2)		
L. pratensis	I	(2-3)	I	(2-3)
Leontodon hispidus	I	(1-4)	I	(1-2)
Leucanthemum vulgare	I	(1-3)	I	(1-2)
Ophioglossum vulgatum	I	(2)		
Pedicularis sylvatica	I	(1-3)		
Polygala vulgaris	I	(1-3)		
Potentilla reptans	I	(1-2)		
Primula veris	I	(1-2)		
Quercus sp.	I	(1)		
Ranunculus bulbosus	I	(1-3)		
Rhinanthus minor	I	(2-3)	I	(1)
Rumex obtusifolius	I	(4)	IV	(1-5)
Senecio sp.	I	(1-3)		
Stellaria graminea	I	(2-3)	I	(1)
Trifolium medium	I	(1)		
Trisetum flavescens	I	(2)		
Veronica chamaedrys	I	(2-4)	I	(1)
V. officinalis	I	(1-2)		
V. serpyllifolia	I	(1-2)	I	(1)
Vicia cracca	I	(2-3)	I	(2)
V. sepium	I	(4)		
Viola riviniana	I	(1)		

Table 8.4 continued

species	Crumpsbrook a	Crumpsbrook b	Valley Park School a	Valley Park School b
Cirsium arvense			II	(1-2)
C. palustre			I	(1)
C. vulgare			I	(1-2)
Crataegus monogyna			I	(1)
Crepis capillaris			I	(1-2)
Elymus repens			I	(1-3)
Epilobium ciliatum			II	(1-2)
E. hirsutum			I	(1)
Geranium molle			I	(1)
Matricaria sp.			I	(1)
Melilotus altissima			I	(1)
Phleum pratense			I	(2)
P. major			I	(1-3)
Poa annua			I	(1)
Polygonum aviculare			I	(1)
R. crispus			I	(1-4)
Sonchus oleraceus			I	(1)
Trifolium dubium			III	(1-5)
Urtica dioica			I	(1)
Veronica arvensis			I	(1-2)
V. sativa			I	(1)
V. tetrasperma			I	(1)

Summary	Crumpsbrook	Valley Park School
mean no. species/quadrat	20.4	21.0
total no. of stands	54	80
total no. of species	74	60

Table 8.5: Analysis of Soils at Crumpsbrook Meadow and Valley Park School (Mean Data).

Parameter	Crumpsbrook	Valley Park School
pH	5.2	7.1
NO_3 (ppm)	<1.0	<1.0
NH_4 (ppm)	6.6	1.7
P (ppm)	5.5	17.0
K (ppm)	91.0	158.8

Table 8.6: Frequency and Abundance of 'Constant Species' at Crumpsbrook Meadow (1988) and Valley Park School Meadow (1989).

a = frequency class, b = domin range, c mean % cover

	Crumpsbrook			Valley Park School		
species	a	b	c	a	b	c
Agrostis capillaris	V	(2-7)	25.80	V	(4-7)	14.06
Anthoxanthum odoratum	V	(2-6)	7.13	V	(4-5)	11.75
Centaurea nigra	V	(1-6)	6.31	V	(2-5)	6.66
Cerastium fontanum	V	(1-3)	1.72	V	(1-3)	2.50
Cynosurus cristatus	V	(2-5)	3.41	V	(2-5)	5.60
Festuca rubra	V	(2-8)	30.93	V	(2-5)	13.63
Holcus lanatus	V	(1-8)	11.67	V	(4-5)	17.59
Plantago lanceolata	V	(1-5)	8.54	V	(2-5)	4.71
Ranunculus acris	V	(1-6)	5.69	V	(1-3)	2.74
Rumex acetosa	V	(1-5)	5.04	V	(1-3)	1.63
Hypochoeris radicata	IV	(1-5)	2.63	III	(1-3)	0.71
Ranunculus repens	IV	(1-7)	3.76	III	(1-3)	0.81
Trifolium pratense	IV	(2-5)	3.61	V	(4-7)	20.98

Table 8.7: Summary of Soil Analysis Results for the Experimental Plots at Valley Park School.

Treatment	NO_3 (mg/kg dry soil)			
	Replicates A	Replicates B	Mean	S.E.
Control	0.5	0.5	0.50	0.00
Turfed	0.5	0.5	0.50	0.00
Maize	1.0	0.5	0.75	0.25
Turfed & Maize	1.3	0.5	0.90	0.40

Treatment	NH_4 (mg/kg dry soil)			
	Replicates A	Replicates B	Mean	S.E.
Control	1.3	1.4	1.35	0.05
Turfed	2.1	2.7	2.40	0.30
Maize	2.1	1.1	1.60	0.50
Turfed & Maize	1.3	1.1	1.20	0.10

Treatment	Available Phosphorus (mg/l)			
	Replicates A	Replicates B	Mean	S.E.
Control	18.0	19.0	18.50	0.50
Turfed	15.0	19.0	17.00	2.00
Maize	18.0	16.0	17.00	1.00
Turfed & Maize	15.0	14.0	14.50	0.50

Treatment	Available Potassium (mg/l)			
	Replicates A	Replicates B	Mean	S.E.
Control	161.0	174.0	167.50	6.50
Turfed	154.0	166.0	160.00	6.00
Maize	153.0	166.0	159.50	6.50
Turfed & Maize	135.0	151.0	143.00	8.00

Note: a value of 0.5 is used where analysis produced a result of <1.0.

Table 8.8: Floristic Table for Crumpsbrook Meadow (1988) and the Experimental Plots at Valley Park School Meadow (1989)

a = frequency class b = domin range.

	Crumpsbrook		Valley Park School Meadow							
			Control		Crop		No Turf		No Turf & Crop	
species	a	b	a	b	a	b	a	b	a	b
Agrostis capillaris	V	(2-7)	V	(4-5)	V	(4-7)	V	(4-5)	V	(4-5)
Anthoxanthum odoratum	V	(2-6)	V	(4-5)	V	(4-5)	V	(4-5)	V	(4-5)
Centaurea nigra	V	(1-6)	V	(2-5)	V	(3-4)	V	(3-5)	V	(3-5)
Cerastium fontanum	V	(1-3)	V	(1-3)	V	(1-3)	V	(2-3)	V	(1-3)
Cynosurus cristatus	V	(2-5)	V	(2-5)	V	(3-5)	V	(2-4)	V	(3-4)
Festuca rubra	V	(2-8)	V	(4-5)	V	(2-5)	V	(3-5)	V	(3-5)
Holcus lanatus	V	(1-8)	V	(4-5)	V	(4-5)	V	(4-5)	V	(4-5)
Plantago lanceolata	V	(1-5)	V	(2-5)	V	(3-4)	V	(2-4)	V	(2-4)
Ranunculus acris	V	(1-6)	V	(2-3)	V	(1-3)	V	(2-3)	V	(3)
Rumex acetosa	V	(1-5)	V	(1-3)	IV	(1-3)	V	(1-2)	V	(1-3)
Hypochoeris radicata	IV	(1-5)	II	(1)	IV	(1-2)	III	(1)	IV	(1-3)
Ranunculus repens	IV	(1-7)	III	(1-3)	II	(1-2)	II	(1-3)	III	(1-3)
Trifolium pratense	IV	(2-5)	V	(4-7)	V	(4-7)	V	(4-7)	V	(4-7)
Dactylis glomerata	III	(2-8)	III	(2-4)	III	(1-5)	III	(2)	III	(1-4)
Leontodon autumnalis	III	(1-3)	IV	(1-3)	III	(1-2)	V	(1-4)	IV	(1-2)
Lotus corniculatus	III	(2-8)	I	(2-3)	II	(1-4)	II	(1-2)	II	(2-4)
Luzula campestris	III	(1-3)								
Prunella vulgaris	III	(1-4)	IV	(2-3)	IV	(1-3)	IV	(1-3)	V	(1-3)
Succisa pratensis	III	(1-6)	I	(1)	II	(1)	I	(1-2)	II	(1-4)
Achillea millefolium	II	(1-4)								
Alopecurus pratensis	II	(2-9)	I	(2-5)	I	(1-2)	I	(2-4)	I	(2)
Bellis perennis	II	(1-3)			I	(1-2)	I	(1-2)	I	(2)
Briza media	II	(1-3)								
Conopodium majus	II	(1-3)								
Lolium perenne	II	(2-4)	I	(4)	I	(2)	I	(2)	I	(1-4)
L. uliginosus	II	(1-6)								
P. trivialis	II	(2-9)	V	(2-3)	V	(1-2)	V	(1-2)	V	(2)
Potentilla erecta	II	(1-4)					I	(1)	I	(1)
Taraxacum spp.	II	(1-4)	III	(1-4)	V	(1-4)	IV	(1-4)	IV	(1-4)
T. repens	II	(2-4)	V	(2-5)	V	(3-5)	V	(2-5)	V	(2-5)

Table 8.8 continued

species	Crumpsbrook 1988 a	Crumpsbrook 1988 b	Valley Park School Meadow: Control a	Control b	Crop a	Crop b	No Turf a	No Turf b	No Turf & Crop a	No Turf & Crop b
Agrostis stolonifera	I	(2)	I	(2-4)			I	(1)	I	(2)
Ajuga reptans	I	(1-2)								
Alchemilla vestita	I	(1-5)								
Anemone nemorosa	I	(2)								
Arrhenatherum elatius	I	(2)								
Betonica officinalis	I	(2)								
Botrychium lunaria	I	(1)								
Bromus hordeaceus	I	(1-2)	I	(1-2)	I	(2)	I	(1)	I	(1-3)
Campanula rotundifolia	I	(2-4)								
Cardamine pratense	I	(1-2)								
Carex caryophyllea	I	(2)								
C. flacca	I	(1-2)								
C. hirta	I	(1)								
Dactylorhiza fuchsii	I	(1-3)								
Euphrasia officinalis agg.	I	(1-4)	I	(1)	I	(2)	I	(1)	I	(1)
Festuca pratensis	I	(1-4)	II	(2-4)	I	(4)	I	(2-4)	II	(1-4)
Heracleum sphondylium	I	(4)								
Hieracium pilosella	I	(1-2)								
Hyacinthoides non-scripta	I	(2)								
Juncus bufonius	I	(1)								
J. conglomeratus	I	(2)								
Lathyrus montanus	I	(2)								
L. pratensis	I	(2-3)	I	(2)					I	(3)
Leontodon hispidus	I	(1-4)	I	(2)	I	(1)				
Leucanthemum vulgare	I	(1-3)	I	(2)	I	(2)	I	(1-2)	I	(1-2)
Ophioglossum vulgatum	I	(2)								
Pedicularis sylvatica	I	(1-3)								
Polygala vulgaris	I	(1-3)								
Potentilla reptans	I	(1-2)								
Primula veris	I	(1-2)								
Quercus sp.	I	(1)								
Ranunculus bulbosus	I	(1-3)								
Rhinanthus minor	I	(2-3)			I	(1)			I	(1)
Rumex obtusifolius	I	(4)	III	(1-4)	III	(1-4)	III	(1-5)	V	(1-4)
Senecio sp.	I	(1-3)								
Stellaria graminea	I	(2-3)							I	(1)
Trifolium medium	I	(1)								
Trisetum flavescens	I	(2)								
Veronica chamaedrys	I	(2-4)							I	(1)
V. officinalis	I	(1-2)								
V. serpyllifolia	I	(1-2)					I	(1)		
Vicia cracca	I	(2-3)	I	(2)						
V. sepium	I	(4)								
Viola riviniana	I	(1)								

Table 8.8 continued

species	Crumpsbrook a	Crumpsbrook b	Valley Park School Meadow: Control a	Control b	Crop a	Crop b	No Turf a	No Turf b	No Turf & Crop a	No Turf & Crop b
Cirsium arvense			I	(1-2)	I	(1-2)	II	(1-2)	II	(1-2)
C. palustre							I	(1)		
C. vulgare			I	(1)			I	(1-2)	I	(1)
Crataegus monogyna							I	(1)		
Crepis capillaris			I	(1-2)	I	(1)	II	(1-2)		
Elymus repens					I	(1-3)	I	(2)	I	(1)
Epilobium ciliatum			II	(1)	III	(1-2)	III	(1-2)	II	(1-2)
E. hirsutum									I	(1)
Geranium molle							I	(1)		
Matricaria sp.			I	(1)	I	(1)	I	(1)	I	(1)
Melilotus altissima									I	(1)
Phleum pratense			I	(2)	I	(2)				
P. major			II	(1-3)	I	(1)	I	(1)	II	(1)
Poa annua					I	(1)	I	(1)		
Polygonum aviculare			I	(1)	I	(1)	I	(1)		
R. crispus			I	(1-2)	I	(1)	II	(1-4)		
Sonchus oleraceus			I	(1)	I	(1)	I	(1)		
Trifolium dubium			II	(1-3)	III	(1-5)	III	(2-4)	II	(1-4)
Urtica dioica							I	(1)		
Veronica arvensis			I	(2)	I	(1-2)	I	(1)	I	(1)
V. sativa									I	(1)
V. tetrasperma							I	(1)		

Summary	Crumpsbrook	Valley Park School Meadow: Control	Crop	No Turf	No Turf & Crop
mean no. of species per quadrat	20.4	20.3	20.2	21.8	21.7
total no. of stands	54	20	20	20	20
total no. of species	74	44	44	50	46

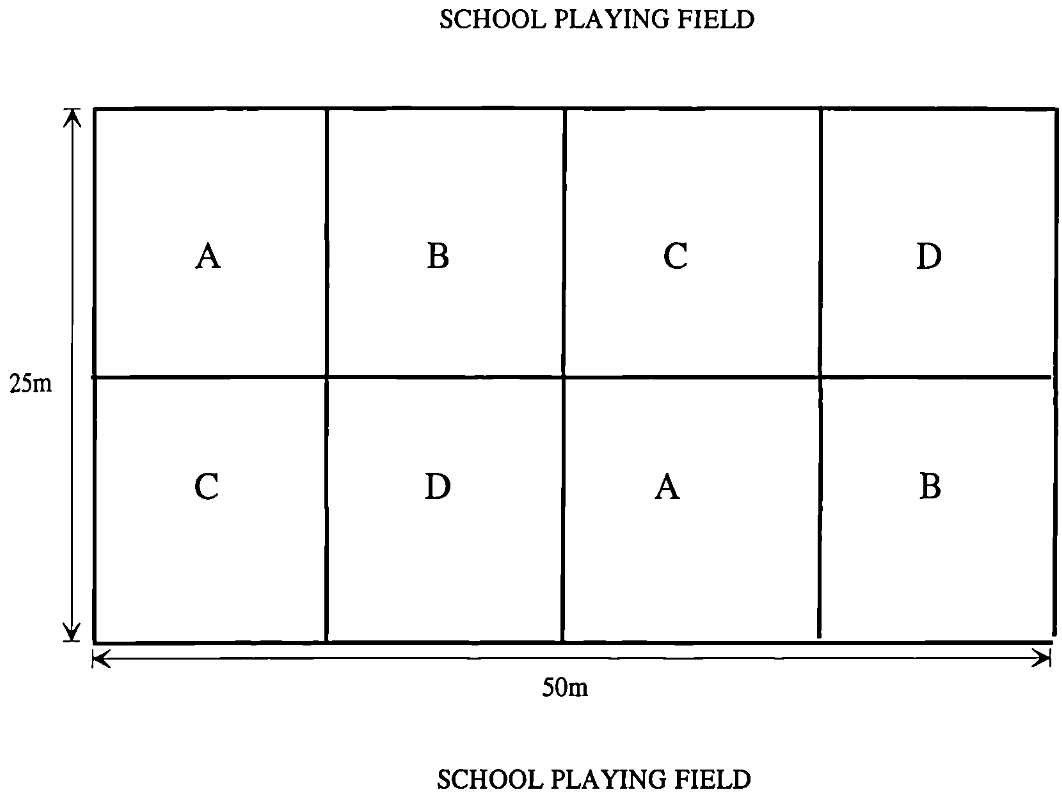
Table 8.9: Frequency and Abundance of 'Constant Species' at Crumpsbrook Meadow (1988) and the Experimental Plots at Valley Park School Meadow (1989).

a = frequency class, b = domin range, c mean % cover

	Crumpsbrook			Valley Park School Meadow											
				Control			Crop			No Turf			No Turf & Crop		
species	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Agrostis capillaris	V	(2-7)	25.80	V	(4-5)	13.70	V	(4-7)	14.35	V	(4-5)	12.95	V	(4-5)	15.25
Anthoxanthum odoratum	V	(2-6)	7.13	V	(4-5)	12.55	V	(4-5)	11.70	V	(4-5)	11.00	V	(4-5)	11.75
Centaurea nigra	V	(1-6)	6.31	V	(2-5)	6.60	V	(3-4)	5.00	V	(3-5)	7.05	V	(3-5)	8.00
Cerastium fontanum	V	(1-3)	1.72	V	(1-3)	2.25	V	(1-3)	2.80	V	(2-3)	2.55	V	(1-3)	2.40
Cynosurus cristatus	V	(2-5)	3.41	V	(2-5)	5.10	V	(3-5)	5.85	V	(2-4)	5.65	V	(3-4)	5.80
Festuca rubra	V	(2-8)	30.93	V	(4-5)	11.90	V	(2-5)	11.95	V	(3-5)	13.50	V	(3-5)	13.15
Holcus lanatus	V	(1-8)	11.67	V	(4-5)	17.95	V	(4-5)	16.85	V	(4-5)	18.05	V	(4-5)	17.50
Plantago lanceolata	V	(1-5)	8.54	V	(2-5)	4.80	V	(3-4)	5.00	V	(2-4)	3.70	V	(2-4)	5.35
Ranunculus acris	V	(1-6)	5.69	V	(2-3)	2.70	V	(1-3)	2.45	V	(2-3)	2.80	V	(3)	3.00
Rumex acetosa	V	(1-5)	5.04	V	(1-3)	1.75	IV	(1-3)	1.30	V	(1-2)	1.55	V	(1-3)	1.90
Hypochoeris radicata	IV	(1-5)	2.63	II	(1)	0.40	IV	(1-2)	0.90	III	(1)	0.55	IV	(1-3)	1.00
Ranunculus repens	IV	(1-7)	3.76	III	(1-3)	1.00	II	(1-2)	0.55	II	(1-3)	0.80	III	(1-3)	0.90
Trifolium pratense	IV	(2-5)	3.61	V	(4-7)	19.45	V	(4-7)	19.85	V	(4-7)	21.10	V	(4-7)	23.20

FIGURES

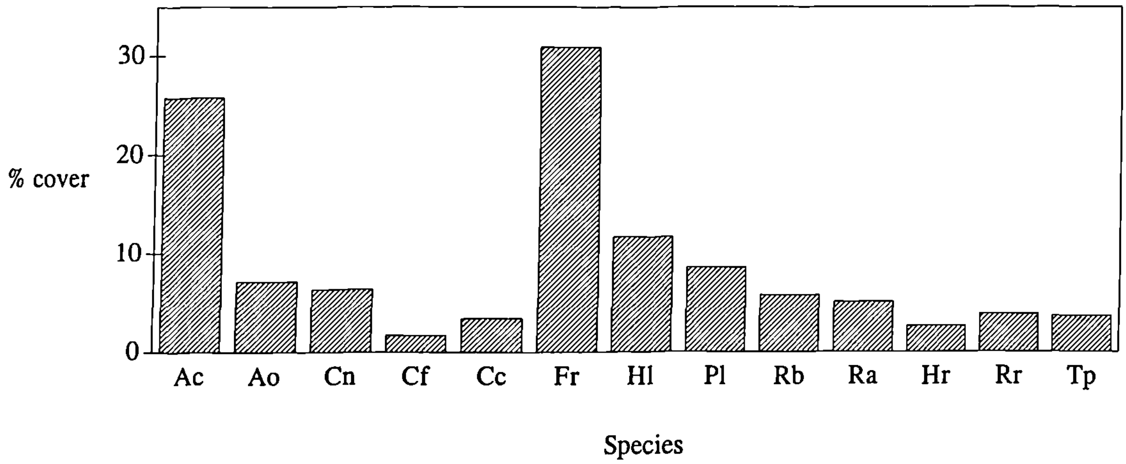
Figure 8.1: Plan of the Experimental Area at Valley Park School, Wolverhampton, Showing the Relative Positions of the Plots (Not to Scale).



Key:

A = Control (no crop and turf retained
B = Turf removed only
C = Maize grown only
D = Turf removed and crop grown

Figure 8.2: Histogram Showing the Mean % Cover of Constant Species at Crumpsbrook Meadow (1988)

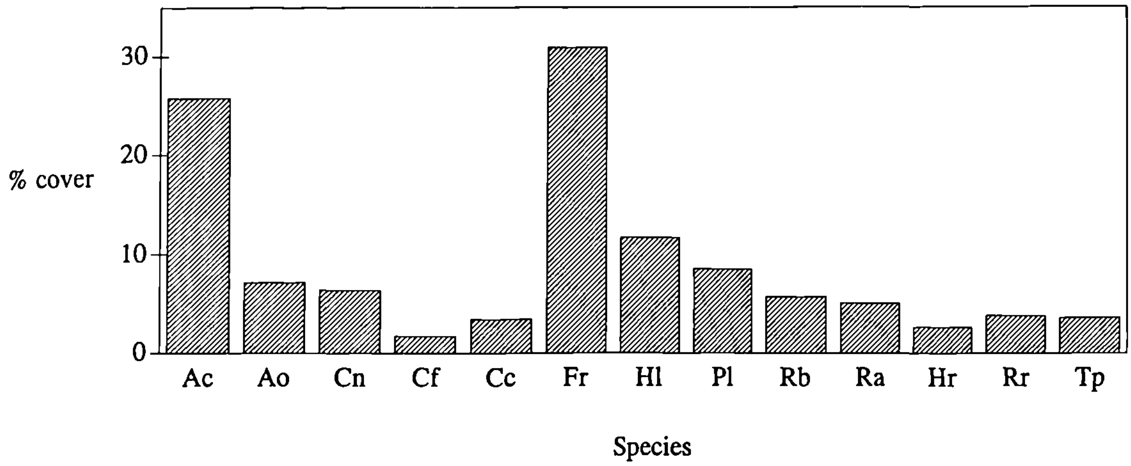


CONSTANT SPECIES

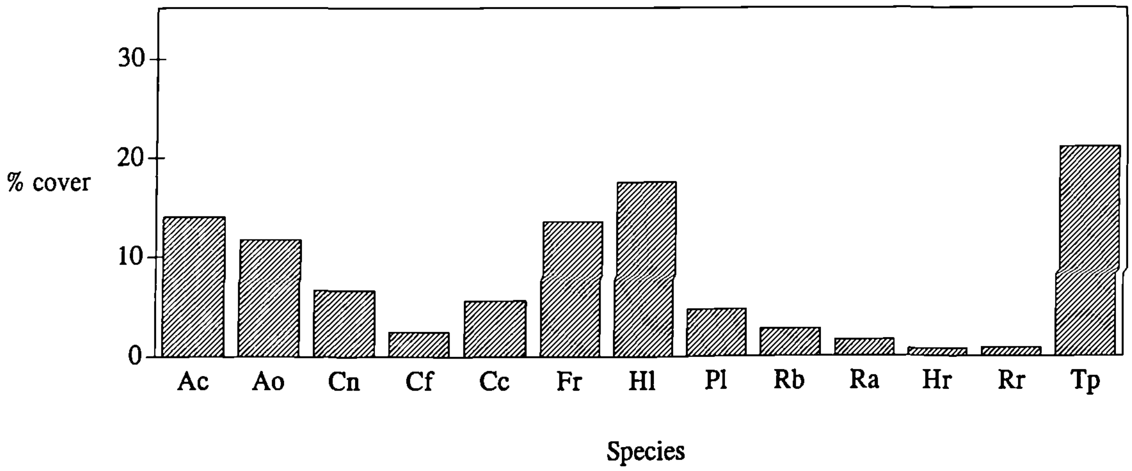
Agrostis capillaris (Ac)
Anthoxanthum odoratum (Ao)
Centaurea nigra (Cn)
Cerastium fontanum (Cf)
Cynosurus cristatus (Cc)
Festuca rubra (Fr)
Holcus lanatus (Hl)
Plantago lanceolata (Pl)
Ranunculus acris (Rb)
Rumex acetosa (Ra)
Hypochoeris radicata (Hr)
Ranunculus repens (Rr)
Trifolium pratense (Tp)

Figure 8.3: Histogram Showing the Mean % Cover of Constant Species at Crumpsbrook Meadow and Valley Park School Meadow

- CRUMPSBROOK MEADOW (1988)



- VALLEY PARK SCHOOL MEADOW (1989) - TOTAL



CONSTANT SPECIES

Agrostis capillaris (Ac)
Anthoxanthum odoratum (Ao)
Centaurea nigra (Cn)
Cerastium fontanum (Cf)
Cynosurus cristatus (Cc)
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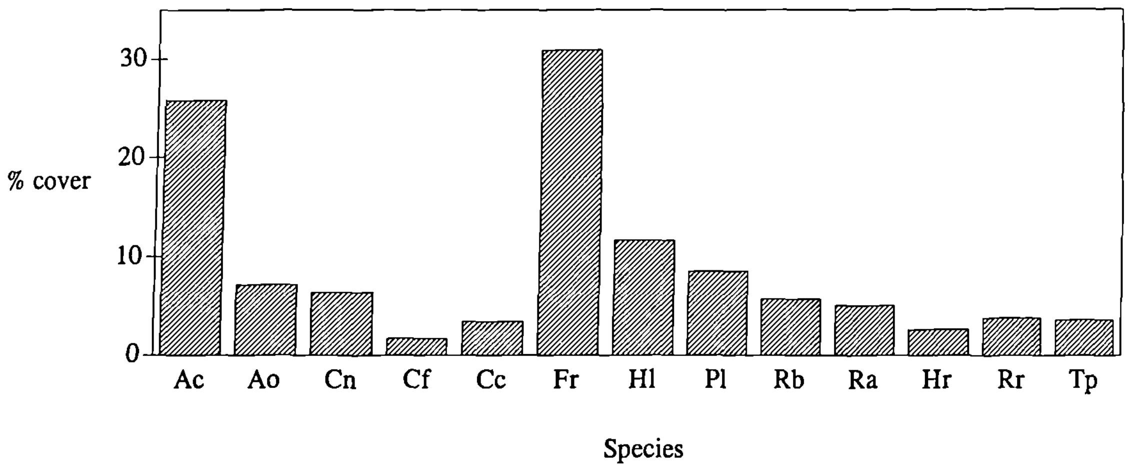
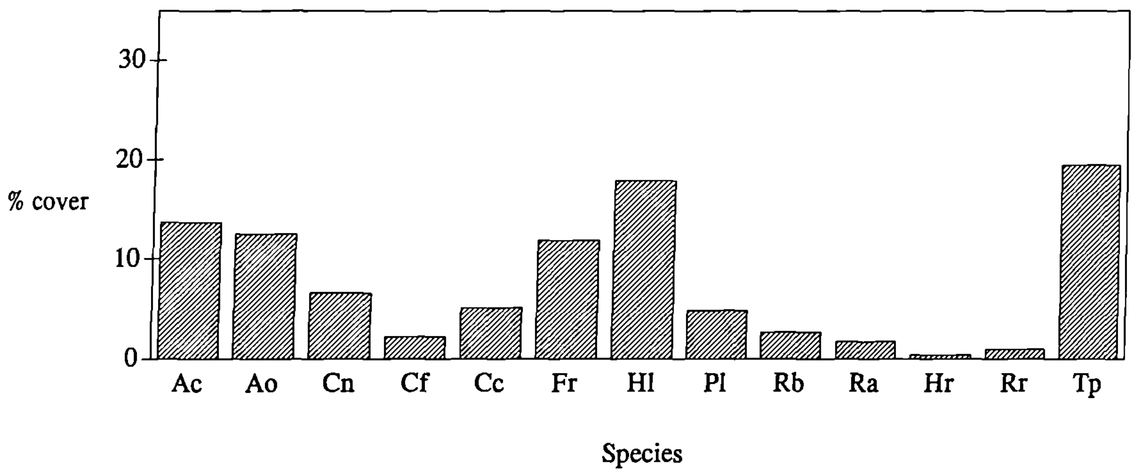
Plantago lanceolata (Pl)
Ranunculus acris (Rb)
Rumex acetosa (Ra)
Hypochoeris radicata (Hr)
Ranunculus repens (Rr)
Trifolium pratense (Tp)

Figure 8.4: Histogram Showing the Mean % Cover of Constant Species at Crumpsbrook Meadow and in the Experimental Plots at Valley Park School

- CRUMPSBROOK MEADOW (1988)



- VALLEY PARK SCHOOL MEADOW (1989) - CONTROL PLOTS



- VALLEY PARK SCHOOL MEADOW (1989) - CROPPED PLOTS

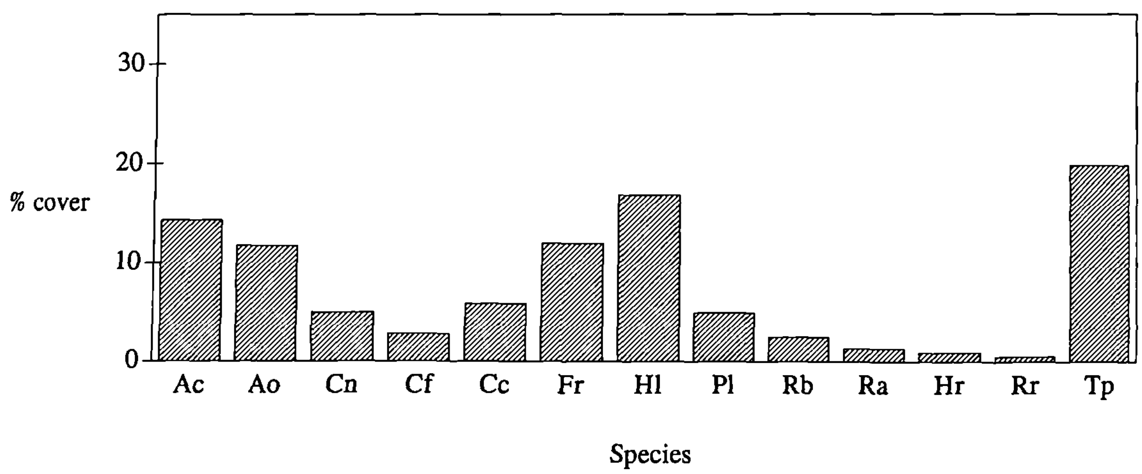
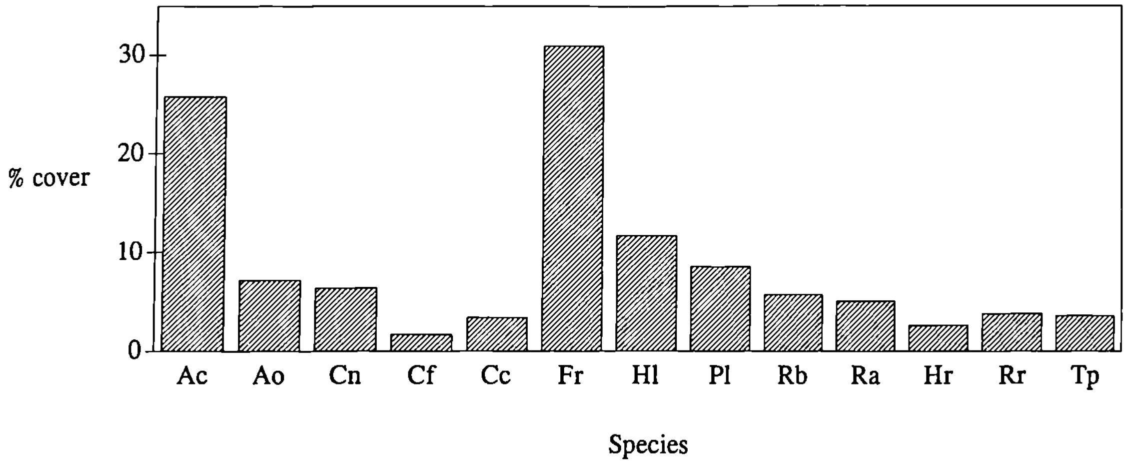
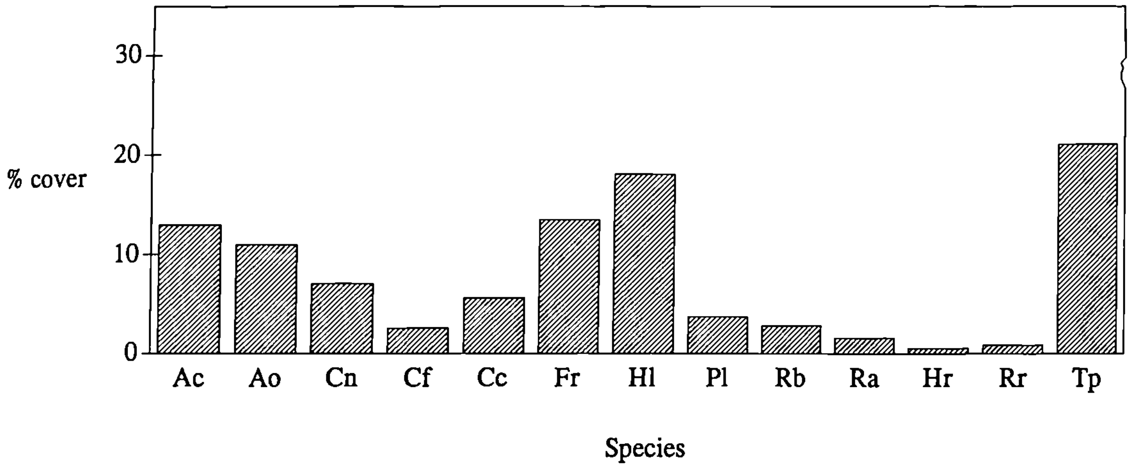


Figure 8.4 Continued:

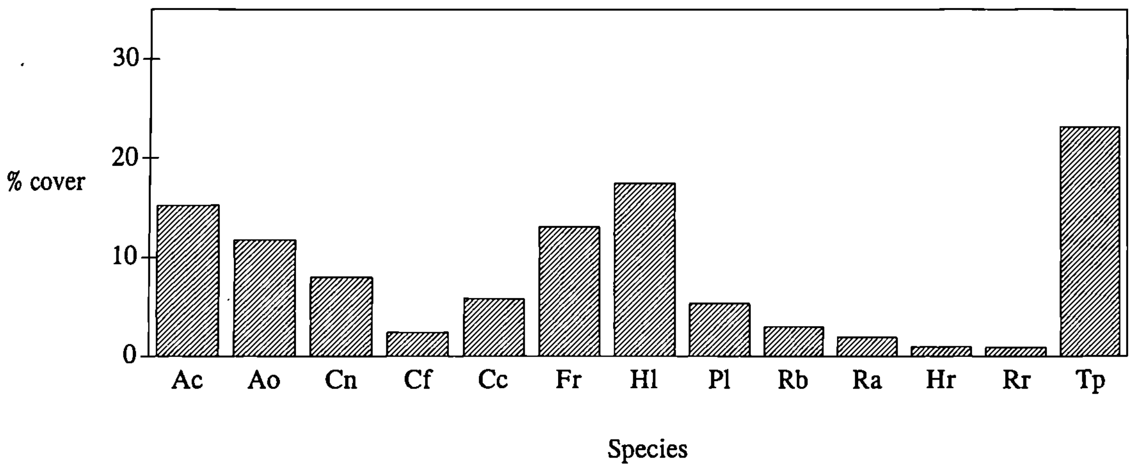
- CRUMPSBROOK MEADOW (1988)



- VALLEY PARK SCHOOL MEADOW (1989) - TURF STRIPPED PLOTS



- VALLEY PARK SCHOOL MEADOW (1989) - BOTH TREATMENTS



CHAPTER 9

The Use of Hay Strewing to Create a Damp Pasture Community

9.0 The Use of Hay Strewing to Create a Damp Pasture Community

9.1 Introduction

Most of the meadow creation work undertaken in Wolverhampton has involved the use of hay from Pennerley Meadows which supports a dry meadow community. However, Chapter 8 considered the use of hay strewing to reproduce the grassland community of a damp meadow and in this chapter an experiment is described in which the same approach was used in an attempt to replicate that of a damp pasture.

Although damp sites are scarce in Wolverhampton, the Council does own an area of damp, derelict agricultural land at Barnhurst Lane, Pendeford (SJ 888029) on the north-western boundary of the Borough. Prior to the experiment the Barnhurst Lane site supported rank grassland dominated by coarse grasses, *Arrhenatherum elatius* and *Dactylis glomerata* being the most abundant. Forbs were infrequent at the site and generally restricted to species indicative of rich but neglected land such as *Anthriscus sylvestris* and *Urtica dioica*. The grassland was separated from neighbouring farmland by a wide, neglected hawthorn hedgerow, and had presumably been abandoned due to the difficult site access, a high water table and periodic flooding by an adjacent stream.

The Council had plans to develop the whole of the Barnhurst Lane site into a local amenity feature/nature reserve and a small area (c. 550m^2) was made available for a meadow creation experiment as part of this scheme.

A donor site for the experiment was found at Hemm Pasture, an area of neglected but botanically diverse pasture near to Corley in South Shropshire (SO 612738). At the time of the experiment the ownership of the pasture had recently changed hands and grazing with dairy cattle had been resumed.

The donor pasture was approximately 3 acres in extent and listed as a Prime Site for Nature Conservation by the Shropshire Wildlife Trust on account of its botanical interest. The most diverse areas were low-lying and periodically flooded by an adjacent stream and therefore similar to the Barnhurst Lane site in Wolverhampton. The silty soil in the wettest areas of the pasture probably never dried out and supported a diverse marshy grassland flora. The community was dominated by *Holcus lanatus* and *Agrostis capillaris* whilst *Juncus articulatus*, *J. acutiflorus* and *Filipendula ulmaria* were locally abundant and formed distinct patches.

Within this matrix, other characteristic marshy grassland species were present in some abundance, including *Cardamine pratensis*, *Cirsium palustre*, *Lotus uliginosus*, *Lychnis flos-cuculi*, *Caltha palustris* and *Valeriana dioica*. A wide range of other species were less common in the Hemm Pasture sward and included species such as *Agrimonia eupatoria*, *Dactylorhiza* spp. and *Pedicularis sylvatica*.

Drier areas of the pasture, on slightly sloping ground away from the stream, also supported a diverse grassland flora. These areas were dominated by *Festuca rubra* and *Agrostis capillaris* whilst other abundant grasses included *Anthoxanthum odoratum*, *Cynosurus cristatus* and *Dactylis glomerata*. A different range of forbs were present in these drier areas and included *Alchemilla filicaulis subsp. vestita*, *Centaurea nigra*, *Lathyrus pratensis*, *Silaum silaus* and *Stachys officinalis*.

The new owner planned to drain and improve the grazing value of the pasture but agreed to allow an area to be used for a hay strewing experiment prior to this. Unfortunately since the experiment, these agricultural improvements were made and the former botanical interest of the site now no longer exists.

During the experiment, no form of replication was attempted, due mainly to the limited area available at Barnhurst Lane. However, an initial inspection of the soils at experimental site in Wolverhampton showed that the rich, organic topsoil present overlay, by approximately 10cm, a relatively poor subsoil with a lower organic content and which contained a higher sand component with some gravel. The removal of top-soil was therefore investigated as an approach to site preparation.

9.2 Methods

9.2.1 Site Preparation and Seeding

An area of Hemm Pasture measuring approximately 0.5ha was available for the experiment and during the spring of 1987 it was fenced off from livestock and allowed to grow for hay. The fenced land contained some areas of drier grassland and the majority of the wettest areas in the pasture, the latter being the richest in terms of botanical diversity but considered by the owner to be of least value in terms of grazing quality.

Preparation of the experimental site began in early August 1987 when the topsoil was removed to a minimum depth of 10cm using a bulldozer. In places more than 10cm were removed leaving several shallow hollows which subsequently filled with water, and thus providing a varied site topography similar to that at the donor site. Following the removal of top soil, the area was harrowed to produce an appropriate seed bed.

On 12 August 1987 the hay within the fenced area of Hemm Pasture was cut by the owner using a tractor mounted drum mower. The following day the hay crop was loaded loose onto a lorry and transported to the experimental site. As access to the experimental site was restricted, the hay was carried from the lorry in sacks to the prepared area and spread by hand. The strewn hay, which formed a loose layer approximately 10-15cm thick, was allowed dry for several weeks before being removed from the site. During the drying period the hay was turned by hand on a number of occasions.

The new grassland was cut using an Allen scythe during August 1988 and the hay removed from the site after a short period during which it was allowed to dry. It was intended that the new grassland be grazed in subsequent years although this has apparently proved difficult for the Council to organise. No grazing has taken place although the created grassland has occasionally been cut for hay.

9.2.2 Survey Methods

The vegetation in the fenced off area at the Hemm Pasture was surveyed in late June 1988. 11 transect lines were run across the area and an estimate made of the percentage cover of plant species present in a 1m x 1m quadrat positioned at five meter intervals along each transect line. A total of 55 quadrats were recorded.

The created grassland was slow to establish. By the summer of 1988 germination was restricted and the sward remained open, with large areas of bare soil. Surveys were therefore postponed and carried out in early July 1989, the second year after seeding. 13 transect lines were run across the experimental area and the percentage cover of species present was estimated in a 1m x 1m quadrat positioned at 2m intervals along each line. A total of 59 quadrats were recorded at the experimental site.

A number of random soil samples were collected to a depth of approximately 12cm from both the experimental area at Barnhurst Lane and Hemm Pasture using an auger with a core diameter of 7cm. The random samples collected at each site were combined and thoroughly mixed before being analysed. Parameters measured were soil pH, nitrogen as ammonium and nitrate, available phosphorus and available potassium. Standard analytical methods were used (MAFF, 1986).

9.3 Results

It was indicated above that the grassland sward at Hemm Pasture was diverse, particularly in the wettest areas. A summary of the results of the survey undertaken at this site are presented in Table 9.1 (p. 243), again using the format adopted previously in this report. A total of 76 plant species were recorded during the survey with a mean number per quadrat of 17.4 species. Although a high total number of species was recorded, the majority of these species were infrequent in the sward, falling into frequency class I. As with previous donor grasslands, and grasslands in general, only a small number of species were recorded at frequencies of 60% or more.

The donor sward was dominated by a limited number of common grassland species, none of which are particularly characteristic of damp or marshy grassland. Species more characteristic of marshy soil conditions were only recorded in frequency classes III and lower. This is due mainly to the fact that the areas of marshy and drier grassland present at the donor site were surveyed together and also that further heterogeneity could be detected in the marshy areas with some species, such as the rushes, forming distinct patches. The use of constant species as a model against which the created sward can be compared is therefore not particularly appropriate during this experiment.

Direct comparison with the floristic tables presented in the draft NVC mesotrophic grassland volume suggest that the donor meadow had the greatest affinity with the MG9 *Holcus lanatus-Deschampsia cespitosa* grassland community. This community is highly characteristic of permanently moist, gleyed and periodically inundated soils (Rodwell, 1992) such as those present in the marshy areas of Hemm Pasture. However the most abundant and characteristic species in this typically species-poor community is *D. cespitosa* and Rodwell (1992) suggests that the physiognomy and composition of the vegetation depend largely on the number, size and disposition of tussocks of this species. It is somewhat surprising, therefore, that *D. cespitosa* was not recorded at Hemm Pasture and the affinity of the donor sward with the MG9 community noted was based purely on the presence and relative abundance of other species associated with this classification. There seems to be no clear reasons for the absence of *D. cespitosa* at Hemm Pasture, in what would appear an ideal habitat. Analysis of the soil of the pasture indicated that it was infertile (Table 9.2: p. 245) and this may have prevented the development of *D. cespitosa*. It is clear, however, that had *D. cespitosa* been present, the grassland sward may not have been as diverse as it was.

The donor pasture also had affinities with MG5 *Centaurea nigra-Cynosurus cristatus* communities, and this is probably a reflection of the inclusion of some of the drier areas in the survey.

The establishment of the created meadow was slow, as was the case at Valley Park School (Chapter 8). It was suggested in the last chapter that wet soils at the experimental site coupled with the particularly wet winter of 1987/88, may have inhibited the establishment of the new grassland. This may also have been the case at Barnhurst Lane. The low-lying position of the site and removal of top soil during site preparation meant that much of the experimental area remained submersed for several months during the first winter.

A summary of the results of the survey of Barnhurst Lane is presented in Table 9.3 (p. 246). The new grassland was similar to the donor pasture in that *Holcus lanatus* and *Agrostis capillaris* were the most abundant grasses. However neither *Festuca rubra* or *Dactylis glomerata* were present and the two rushes *Juncus articulatus* and *J. acutiflorus* which were locally abundant in the donor sward, were only present in the created grassland at low frequencies and low levels of relative abundance.

J. effusus was both frequent and abundant in the created sward but absent from the donor site. It is likely that *J. effusus* was present at the Barnhurst Lane site prior to the experiment and the soil disturbance and removal of vegetation during site preparation may well have encouraged the development of this species. It is amongst the first species to establish in mires on soils bared by disturbance (Grime *et al*, 1988) and it does have persistent seeds which are incorporated into the seed bank. Furthermore, Grime *et al* (1988) note that small seed banks have been detected at sites where there is no historical record of the species suggesting that there is effective dispersal of the seeds through animals or some other agent.

Analysis of the soils at Barnhurst Lane indicated that despite top soil removal, the experimental substrate was particularly rich in terms of available phosphorus and nitrogen as ammonium when compared to the donor site (Table 9.4: p. 248). The levels recorded were equal or in excess of those reported for a range of productive soils by Bradshaw & Chadwick (1980). This may well have accounted for the development of *J. effusus* in place of other rushes, and the lush growth of grasses such as *Holcus lanatus* and *Agrostis* spp.

It is of interest that *Deschampsia cespitosa* formed an frequent and abundant component of the created grassland sward despite its apparent absence at the donor site. *D. cespitosa* was already present in places at the Barnhurst Lane site and appears to have seeded into the bared experimental area.

Filipendula ulmaria was present at lower frequencies in the created sward than at the donor pasture and its relative abundance, where present, remained low. The amount of seed of this species introduced to the Barnhurst Lane site in the hay from Hemm Pasture was known to be high and germination was extensive in the experimental sward in 1988. It was one of the few forbs noted in the relatively open and immature sward present in the first season and seedlings were present in all parts of the site with the exception of those which remained submerged. It is clear, therefore, that the seed introduced was viable but that seedling survival was poor.

There may be a number of reasons for the high seedling mortality rate in *F. ulmaria* at Barnhurst Lane. Grime *et al* (1988) note that it has been suggested that ferrous ion toxicity in waterlogged sites may be a reason for the absence of this species. Much of the Barnhurst Lane remained waterlogged throughout the early part of 1988.

Also the species has a relatively low relative growth rate compared to other stand-forming species and the seedlings at Barnhurst Lane may therefore not have survived competition from the dense grass cover which developed.

F. ulmaria is a species typical of moderately fertile sites. Although the Barnhurst Lane site had high levels of phosphorus and ammonium, low levels of potassium were recorded (Table 9.4: p. 248). In unproductive soils such levels of potassium are likely to be the cause of low productivity in common species (Bradshaw & Chadwick, 1980) and it may be possible that the levels recorded were limiting in terms of the establishment of *F. ulmaria*. They were, however, no different from those recorded at Hemm Pasture where the species was locally abundant.

However, all the above suggestions are hypothetical and untested in the present study and the actual reasons for the high mortality of *F. ulmaria* seedlings therefore remains unclear.

As has been the case in other meadow creation experiments, many of the species recorded at low frequencies (frequency class I) in the donor sward were not recorded during the survey of the experimental site. This is perhaps not surprising as the amount of seed of these species transferred would have been low. Also many of these species are characteristic of more stable conditions and well established swards.

Several marshy grassland species recorded at lower frequencies in the donor site were introduced to the experimental site, however, including *Lychnis flos-cuculi*, *Lysimachia nummularia*, *Ranunculus flammula* and *Valeriana dioica*. In addition *Pedicularis sylvatica* and *Eleocharis palustris*, which although present at the donor site were so infrequent that they was not recorded during the survey, were also introduced to the experimental site. It is very unlikely that any of these species were introduced other than in the hay. Although the created grassland at Barnhurst Lane appeared very different from the attractive grassland at Hemm Pasture at the time of the survey, the introduction of these species is significant and indicates the potential for the sward to develop and improve.

Such an improvement would be dependent on the introduction of a suitably harsh management regime. This has proved impractical at the Barnhurst Lane site, which since the survey has deteriorated due to the lack of such management and the invasion and vigorous growth of *Alnus glutinosa*. This species grows in places adjacent to the stream which borders the experimental area and its small wind dispersed seeds would have found an ideal seed bed in the moist soils present at the experimental site.

In the absence of management since the survey, many *Alnus* seedlings have established and now pose a serious threat to the created grassland. Canopy cover is probably now in excess of 50% of the site and has visibly suppressed the grassland underneath. In places, extremely dense canopy cover has eliminated other ground cover. The created grassland and some of the introduced species have survived to some extent between the patches of *Alnus* and it is possible that the introduction of grazing may produce a recovery.

9.4 Discussion

A number of conclusions can be drawn from the experiment at Barnhurst Lane. Firstly, it appears that the creation of damp grasslands is a slower and more difficult process than the creation of dry grasslands. This conclusion is supported by the results of the experiment at Valley Park School (Chapter 8).

Site hydrology appears to be critical to the germination of many species which, although they may require moisture and are not tolerant of drought, fail to germinate in waterlogged conditions. It is very difficult to manipulate site hydrology and very easy to make mistakes when attempting to do so. Although the hydrology was not intentionally altered at Barnhurst Lane, the removal of top soil resulted in the lowering of the ground surface to such an extent that the site was inundated during wet weather thus inhibiting the germination of many species. It is perhaps for these reasons that so little appears in the literature about the creation or translocation of damp grassland communities.

Potential problems associated with top soil removal on urban sites have been discussed in

Chapter 8. Although the Barnhurst Lane site did not have the problem of unknown or difficult soil sub-layers, it was clear that top soil removal alone did not have the effect of lowering the soil fertility to the extent that it may be considered infertile. The experimental site remained richer than the donor site and this was reflected to some extent in the vegetation which established. Top soil removal is obviously not always an appropriate approach to reducing soil fertility, even when practical. Some sites are inherently fertile and as such not suitable for the creation of non-productive grasslands.

The need for appropriate management of grasslands in general, and created grassland in particular, is well recognised and has been discussed elsewhere in this report. Hay cutting is a practice which can be adopted by local authorities in urban areas with a little modification of current practice, perhaps some investment in new machinery and a degree of re-education of the parks department work force. The introduction of grazing management on the other hand, is generally a much greater challenge in our towns. It is not a practice with which there are many parallels in the traditional approaches to amenity grassland management and if carried out at all in towns, is generally restricted to special places such as urban farms and some nature reserves. Although local farmers may be willing to provide stock at some times of the year, especially where there is a prospect of free grazing, there is generally a great reluctance to do so unless proper controls are put in place. Suitable fencing is essential but often out of the question in urban open spaces. Grazing animals are expensive and it is unlikely that they will be volunteered where there is a danger of 'vandalism'.

But possibly most important is the fact that control of grazing is a fine art which requires constant supervision. Farmers 'read the land' and know when grazing is too intense or when more animals are needed and they usually have the capacity to instigate the appropriate changes. It is therefore not a simple matter of re-education, greater investment or modification to existing practice when attempting to introduce grazing management in urban areas and thus more likely to fail.

It may be concluded that attempts to reproduce semi-natural pastures are ill advised in urban areas. Even at Barnhurst Lane, a relatively secure and secluded site on the edge of the Borough, the introduction of grazing proved to be difficult to organise and the resultant deterioration in the grassland was rapid. Although some success was achieved at introducing species from the donor pasture using the hay strewing approach, the ultimate success was dependent of the introduction of appropriate management. The grassland has occasionally been cut for hay in place of grazing since its establishment but the experiment shows that you obviously can not make a pasture be a meadow just by changing the management.

TABLES

Table 9.1: Floristic Table for Hemm Pasture (1988)

a = frequency class, b = domin range.

Species	Hemm a	Pasture b
Agrostis capillaris	V	(2-9)
Festuca rubra	V	(2-8)
Holcus lanatus	V	(2-9)
Rumex acetosa	V	(1-4)
Cerastium fontanum	IV	(1-3)
Dactylis glomerata	IV	(2-7)
Lathyrus pratensis	IV	(1-3)
Poa trivialis	IV	(2-5)
Potentilla erecta	IV	(1-4)
Anthoxanthum odoratum	III	(2-4)
Centaurea nigra	III	(1-4)
Cirsium palustre	III	(1-4)
Cynosurus cristatus	III	(2-3)
Juncus articulatus	III	(1-8)
Lotus corniculatus	III	(1-3)
L. uliginosus	III	(1-4)
Ranunculus acris	III	(1-3)
Cardamine pratensis	II	(1-3)
Cirsium arvense	II	(1-5)
Filipendula ulmaria	II	(1-7)
Galium palustre	II	(1-3)
Luzula campestris	II	(1-3)
Plantago lanceolata	II	(1-3)
Ranunculus repens	II	(1-4)
Stachys officinalis	II	(1-4)
Achillea millefolium	I	(1-5)
Alchemilla filicaulis vestita	I	(1-4)
Alopecurus pratensis	I	(2)
Arrhenatherum elatius	I	(2)
Briza media	I	(1)
Caltha palustris	I	(1-4)
Carex hirta	I	(1)
C. nigra	I	(2)
C. pallescens	I	(3)
Conopodium majus	I	(1-2)
Equisetum arvense	I	(1)
Festuca pratensis	I	(2-4)
Galium aparine	I	(1)
Glyceria fluitans	I	(2)
Glechoma hederacea	I	(1-2)
Heracleum sphondylium	I	(1-4)
Hypochoeris radicata	I	(2-3)
Juncus acutiflorus	I	(4-7)
J. conglomeratus	I	(2-3)
J. inflexus	I	(5)

Table 9.1 continued

Species	Hemm Pasture a	b
Leontodon autumnalis	I	(1)
Lolium perenne	I	(2)
Lychnis flos-cuculi	I	(2-3)
Lysimachia nummularia	I	(2-3)
L. nemorum	I	(1)
Mentha arvensis	I	(1-4)
Myosotis laxa caespitosa	I	(1)
Phalaris arundinacea	I	(2)
Phleum pratense	I	(2-3)
Potentila anserina	I	(2)
P. reptans	I	(2-3)
P. sterilis	I	(2-3)
Prunella vulgaris	I	(1)
Pteridium aquilinum	I	(1-2)
Ranunculus flammula	I	(1-2)
Rubus fruticosus agg.	I	(1)
Rumex obtusifolius	I	(3)
Senecio sp.	I	(1-3)
Senecio aquaticus	I	(4)
Silaum silaus	I	(1)
Stellaria alsine	I	(2)
S. media	I	(1)
Succisa pratensis	I	(1-2)
Taraxacum spp.	I	(1-2)
Trifolium pratense	I	(1-2)
T. repens	I	(2)
Trisetum flavescens	I	(2-4)
Urtica dioica	I	(1-4)
Valeriana dioica	I	(2-4)
Veronica chamaedrys	I	(1-4)
Vicia cracca	I	(1-2)

Summary	Hemm Pasture
mean no. species/quadrat	17.4
total no. of stands	55
total no. of species	76

Table 9.2: Analysis of Soils at Hemm Pasture (Mean Data)

	Hemm Pasture
pH	6.1
NO_3 (ppm)	<1.0
NH_4 (ppm)	3.7
P (ppm)	3.0
K (ppm)	66.0

Table 9.3: Floristic Table for Hemm Pasture (1988) and Barnhurst Lane (1989).

a = frequency class, b = domin range.

Species	Hemm Pasture a	Hemm Pasture b	Barnhurst Ln. a	Barnhurst Ln. b
Agrostis capillaris	V	(2-9)	V	(2-10)
Festuca rubra	V	(2-8)	-	-
Holcus lanatus	V	(2-9)	V	(2-8)
Rumex acetosa	V	(1-4)	IV	(1-3)
Cerastium fontanum	IV	(1-3)	II	(1-3)
Dactylis glomerata	IV	(2-7)	-	-
Lathyrus pratensis	IV	(1-3)	-	-
Poa trivialis	IV	(2-5)	I	(1)
Potentilla erecta	IV	(1-4)	II	(1-3)
Anthoxanthum odoratum	III	(2-4)	III	(2-4)
Centaurea nigra	III	(1-4)	III	(1-4)
Cirsium palustre	III	(1-4)	III	(1-4)
Cynosurus cristatus	III	(2-3)	I	(1)
Juncus articulatus	III	(1-8)	I	(2-5)
Lotus corniculatus	III	(1-3)	-	
L. uliginosus	III	(1-4)	II	(1-4)
Ranunculus acris	III	(1-3)	I	(1-2)
Cardamine pratensis	II	(1-3)	I	(1-2)
Cirsium arvense	II	(1-5)	-	-
Filipendula ulmaria	II	(1-7)	I	(1-3)
Galium palustre	II	(1-3)	III	(1-3)
Luzula campestris	II	(1-3)	I	(1-2)
Plantago lanceolata	II	(1-3)	II	(1-4)
Ranunculus repens	II	(1-4)	V	(1-8)
Stachys officinalis	II	(1-4)	-	-
Achillea millefolium	I	(1-5)	-	-
Alchemilla filicaulis vestita	I	(1-4)	-	-
Alopecurus pratensis	I	(2)	I	(1-5)
Arrhenatherum elatius	I	(2)	-	-
Briza media	I	(1)	-	-
Caltha palustris	I	(1-4)	-	-
Carex hirta	I	(1)	-	-
C. nigra	I	(2)	-	-
C. pallescens	I	(3)	-	-
Conopodium majus	I	(1-2)	-	-
Equisetum arvense	I	(1)	-	-
Festuca pratensis	I	(2-4)	I	(1-5)
Galium aparine	I	(1)	-	-
Glyceria fluitans	I	(2)	I	(2-7)
Glechoma hederacea	I	(1-2)	-	-
Heracleum sphondylium	I	(1-4)	-	-
Hypochoeris radicata	I	(2-3)	I	(1-2)
Juncus acutiflorus	I	(4-7)	I	(1-2)
J. conglomeratus	I	(2-3)	II	(1-5)
J. inflexus	I	(5)	I	(1-2)

Table 9.3 continued

Species	Hemm Pasture a	b	Barnhurst Ln. a	b
Leontodon autumnalis	I	(1)	I	(1-2)
Lolium perenne	I	(2)	I	(2)
Lychnis flos-cuculi	I	(2-3)	I	(1-2)
Lysimachia nummularia	I	(2-3)	I	(1-2)
L. nemorum	I	(1)	-	-
Mentha arvensis	I	(1-4)	-	-
Myosotis laxa caespitosa	I	(1)	-	-
Phalaris arundinacea	I	(2)	-	-
Phleum pratense	I	(2-3)	-	-
Potentila anserina	I	(2)	-	-
P. reptans	I	(2-3)	-	-
P. sterilis	I	(2-3)	-	-
Prunella vulgaris	I	(1)	-	-
Pteridium aquilinum	I	(1-2)	-	-
Ranunculus flammula	I	(1-2)	I	(1-3)
Rubus fruticosus agg.	I	(1)	-	-
Rumex obtusifolius	I	(3)	I	(1)
Senecio sp.	I	(1-3)	-	-
Senecio aquaticus	I	(4)	I	(1-4)
Silaum silaus	I	(1)	-	-
Stellaria alsine	I	(2)	-	-
S. media	I	(1)	-	-
Succisa pratensis	I	(1-2)	-	-
Taraxacum spp.	I	(1-2)	-	-
Trifolium pratense	I	(1-2)	I	(2)
T. repens	I	(2)	-	-
Trisetum flavescens	I	(2-4)	-	-
Urtica dioica	I	(1-4)	-	-
Valeriana dioica	I	(2-4)	I	(1-2)
Veronica chamaedrys	I	(1-4)	-	-
Vicia cracca	I	(1-2)	-	-
Agrostis gigantea	-	-	II	(4-7)
A. stolonifera	-	-	I	(2-8)
Alnus glutinosa (seedlings)	-	-	III	(1-5)
Alopecurus geniculatus	-	-	I	(2)
Crataegus monogyna (seedling)	-	-	I	(1)
Deschampsia cespitosa	-	-	IV	(4-8)
Eleocharis palustris	-	-	I	(2-5)
Epilobium ciliatum	-	-	I	(1-2)
Isolepis setacea	-	-	I	(1)
Juncus bulbosus	-	-	I	(2-5)
J. effusus	-	-	III	(2-7)
Mentha aquatica	-	-	I	(1)
Pedicularis sylvatica	-	-	I	(1-4)
Polygonum persicaria	-	-	I	(1)
Quercus robur (seedling)	-	-	I	(1)
Salix fragilis (cutting)	-	-	I	(1)

Summary	Hemm Pasture	Barnhurst Ln.
mean no. species/quadrat	17.4	11.8
total no. of stands	55	59
total no. of species	76	51

Table 9.4: Analysis of Soils at Hemm Pasture and Barnhurst Lane.

	Hemm Pasture	Barnhurst Lane
pH	6.1	5.5
NO_3 (ppm)	<1.0	1.0
NH_4 (ppm)	3.7	19.0
P (ppm)	3.0	58.5
K (ppm)	66.0	65.5

CHAPTER 10

General Discussion

10.0 General Discussion

The recent explosion in interest in habitat creation is seen by some as presenting opportunities of enormous scale. Baines (1988) suggests that over a thousand million pounds are spent each year in this country maintaining municipal grasslands, many of which provide little in the way of ecological interest or social stimulation. Much of this amenity grassland would benefit from a little imaginative manipulation of management or other enhancement and it would seem that habitat creation undoubtedly has an important role in these areas.

It is also clear that habitat creation and restoration has great value as an ecological learning tool (Jordan *et al*, 1987: Bradshaw, 1983). It is generally accepted that one of the best ways to understand how something works is to try and build it. Bradshaw (1983 & 1987) considers the successful restoration of an ecosystem as the acid test of ones ecological understanding.

However, the growth in interest in habitat creation does also presents a number of ecological problems.

Sites for habitat creation must be chosen with caution, not just because of the potential physical constraints a particular site may present. Sites which have not been fertilised and where the soil nutrient base is low, may already support plant and animal communities of conservation importance and only require small changes to current management for their enhancement.

Furthermore, urban wasteland or other derelict land sites, which are often seen as undesirable and may be considered by local authorities as appropriate for enhancement using naturalistic landscaping and habitat creation techniques, also often support plant communities of great ecological significance and value (Gilbert, 1989; Dawe, in press). Indeed, Gilbert (1989) considers the expansion of wasteland in towns to be one of the most significant events in recent years in ecological terms. He regards what have been termed 'urban commons' as a landscape asset, suggesting that they provide "pockets of complexity and unpredictability" which are rich in types of wildlife that do not occur in the countryside. The intrinsic value of 'urban commons' is recognised by the present author, who gained some of his earliest practical ecological experience through studies of urban sites (Jones, 1986). In ecological terms, such sites are unsuitable for habitat creation as this would typically result in important plant and animal communities being replaced by less important ones.

Clearly, ancient habitats can never be fully reproduced by artificial means, even if the diversity of species present can. The history of ancient woodland, for example, or the natural processes which have resulted in species diversity in old grasslands, are the basis of their 'naturalness'

(Ratcliffe, 1977) and conservation value.

However, it is unfortunate that habitat creation is now frequently misused and offered as mitigation to ecologically destructive development, often without an adequate, research based, precedent (Hopkins, 1989; Sutherland & Gibson, 1988). As a result there is a counter-current to the increased interest in habitat creation developing amongst certain groups. Smyth (1987), for example, pointed out the dangers of actually causing more damage to the ecology of an area than is compensated for by any diversification of vegetation using habitat creation. Sutherland & Gibson (1988) indicate that on disturbed urban sites in Norwich which have been "left to their own devices", more than 150 species of plants have been recorded and argue strongly that in view of the fact that a replacement "wild-flower" mixture may contain as few as 15 species, meadow creation on such a site would be inappropriate and an ecological disaster.

The statutory and voluntary conservation agencies therefore find themselves faced with a dilemma. Promoting research into habitat creation may be seen as the promotion of the concept that habitats of ecological value are reproducable. However, it seems clear that research must continue as recognition of the limitations of habitat creation is now essential for the continued conservation of existing semi-natural habitats.

Jones (1990) has recognised a number of different strategies which are adopted during habitat creation schemes. The most common approach he suggests is full intervention and management to produce a 'target' community. This is carried out on bare or bared sites, and is the approach most frequently discussed in habitat creation manuals (eg. Baines & Smart, 1984; Emery, 1986).

At the other end of the spectrum is the 'do nothing' approach, where there is a total reliance on natural successional processes for the development of new communities. Hopkins (1989) suggests that this approach is attractive to the conservation agencies as the resultant plant community has a high degree of naturalness, although, surprisingly it has not been widely advocated or used by them during habitat creation schemes (Jones, 1990). Ash *et al* (1992) suggest that such a strategy is rarely applicable in the modern landscape and that an area of infertile habitat exposed today is less likely to develop into an attractive wildlife habitat. They suggest that this is due to declines in many native species and the relative isolation of many disturbed sites restricting colonisation to some species growing locally and a small selection of wind dispersed species. However, Gilbert (1989) and many others see the colonisation of urban waste land by wind dispersed species as a important and interesting first successional stage in the development of such sites. Furthermore, many derelict or wasteland sites, particularly those with some types of tipped industrial wastes, may be suitable for colonisation by rarer wind dispersed species (Lee & Greenwood, 1976; Greenwood & Gemmel, 1978; Gemmel, 1982; Bradshaw, 1983).

Intermediate habitat creation strategies involve varying degrees of intervention during establishment or management. The benefits of changing the management on some existing grasslands has been discussed earlier. Some suggest that this is a preferable alternative to full intervention habitat creation (Sutherland & Gibson, 1988), although others, the present author included, believe that both approaches are applicable in different circumstances.

Dawe (in press) suggests a number of commonly adopted objectives for habitat creation schemes ranging from environmental improvement and education to scientific research. As suggested in Chapter 7, Baines (1988 & 1989) believes that these, often mixed, objectives boil down to two basic approaches. Political habitat creation - to improve dire ecological circumstances - he considers as appropriate where simplicity but attractiveness are objectives and even the introduction of non-native species may be considered. He sees this as a valid part of urban landscaping and as a way of educating people to accept non-conventional approaches to this.

Ecological habitat creation Baines sees as the attempt to reproduce complex ecosystems. It is fraught with many more difficulties than its simpler alternative but, he believes, possibly not appreciated any more as part of urban landscaping, particularly as it is more susceptible to failure. If successful, however, it is clear that 'ecological habitat creation' would produce plant communities which may be considered to have a greater scientific validity.

Clearly it is not sensible to expect to recreate exactly the plant and animal assemblages found in a specific semi-natural grassland or other ecosystem. Although broad types of plant communities can be recognised and are the basis for community classification system such as the NVC, they only represent nodes within a continuum. The assemblages present on any one site reflect the specific nature of that site; the precise chemical and physical characteristics of the soil, hydrology, the altitude, aspect, underlying geology and climate. Most of these factors are impossible to reproduce artificially. Indeed, on some sites it is even often difficult to emulate some of the anthropogenic factors which influence the composition of a target plant community, such as management or the level and type of any other forms of disturbance (eg. the difficulty often experienced in instituting grazing regimes in urban areas).

The concept of exact community replication, ie. the ultimate success in terms of Baines' ecological habitat creation, may therefore be an unachievable goal. The objective of ecological habitat creation can only be to produce communities containing a range of species which broadly reflects a recognised community type. Hay strewing, which has been adopted as an approach to grassland creation in Wolverhampton and which has been used throughout the present study, has proved to be a useful approach towards satisfying this objective.

How do you make a 'good' grassland?

This is a question that has now troubled workers for some years. Grassland creation has invariably revolved around the use of commercially available seed mixtures. Much of the basic research has been undertaken, and much of the current practical experience has been gained, using such mixes. Hay strewing has received very little attention in this country. Although it has been suggested as a possibility in various publications, examples of grasslands created using the technique are scarce.

In Chapter 3 & 4 the first meadows created in Wolverhampton using the hay strewing technique were investigated in a quantitative way. The surveys carried out indicated that a degree of success had been achieved during the transfer of the vegetation from the donor meadow to the created meadows and that the created grassland supported the majority of the most characteristic species of the donor plant community.

However, the concept of a 'good' created grassland is obscure and presents difficulties in terms of assessment and evaluation. During the present study, created grasslands have been assessed in terms of their similarity with the donor of the hay with which they were seeded, based upon the comparative frequencies and abundances of the constituent species. Although it seems difficult to envisage a more appropriate method of quantifying the success of a created meadow, it is clear that this comparative approach has its weaknesses. Pennerley Meadows, the donor of hay for the majority of the experiments undertaken, is a distinct plant community and not just a collection of plant species, responding to the physical and chemical conditions prevalent at the site. To use it as a basis for measuring the degree of success achieved during grassland creation on another site is therefore bound to have its limitations. Such a comparison does not indicate whether the created grassland is 'functioning' like a plant community, but just the degree to which it resembles a 'functioning' plant community based upon the species present.

Bearing in mind these limitations, the results in some chapters do tend towards suggesting that it is possible to differentiate between good and less good meadows using this comparative approach and that hay strewing seems to be an approach to replicating actual plant communities. The comparison of frequency and abundance scores represents a subtle bioassay of the success of meadow replication.

Stevens (1988) used hay from a species-rich donor meadow in Dorset during attempts to create a grassland on a nearby site which was attractive to butterflies. Although no quantitative results have been presented for this meadow, Stevens noted a number of broad leaved species and a variety of grasses in the created meadow in the first year following seeding. She saw distinct advantages in obtaining hay from a local source which was already rich in butterfly activity, particularly as any animals actively introduced would also probably be obtained from the donor site.

The advantages of using strewn hay have been discussed previously in this report. They include the introduction of a range of species probably not available commercially, in relative proportions equivalent to a semi-natural grassland. As with Stevens' butterflies, the seeds have a known provenance, which can not always be guaranteed with commercial seed. Furthermore, the seed introduced with hay will not have been stored meaning that overall viability is likely to be higher.

It has become apparent during the present study that freshly cut grass is superior to dried hay in terms of the quantity and species composition of seed transferred. Furthermore, big bales have proved to be a very efficient and convenient method for transferring green hay to a new site (Chapter 5). If labour is in short supply, big baling only requires one man and a tractor to cut the donor meadow, whilst a couple of people can unroll the bales once they have arrived at the new site. It seems that the reduced threshing resulting from baling when compared to loading loose hay may allow more seed to be retained, and thus transferred, in the hay.

The hay strewing approach would seem to be applicable to a range of grassland types, although difficulties were experienced during the present study with wet sites (Chapters 8 & 9). This, however, appeared to be more a result of the difficulties inherent in creating wet grasslands than short-comings in the hay strewing method.

In Chapter 7 it was suggested that hay is cheaper to purchase than equivalent seed mixtures. Although certain aspects of meadow creation using hay will be more expensive, the relative cheapness of the hay can more than compensate for this (Stevens 1988). The hay approach also appears to be a cheap way of experimenting with the introduction of certain species into an established grassland sward (cf. Bushbury Hill plot 4 - Chapter 4).

There may be other, more obscure, advantages of the hay strewing technique. Ries *et al* (1980) indicate that the hay mulch provides both wind and water erosion protection for the tender grass seedlings while they are becoming established. In the experiment described in Chapter 7 it was apparent that the hay mulch may also have a suppressive effect on weed germination. The mechanism for this is unclear but it is possible that many weeds, whose seeds are brought to the surface by soil cultivation, have a light requirement for germination. A hay covering would restrict the amount of light reaching the soil surface, thus preventing germination of weed species until the hay is removed. Meanwhile, some introduced meadow species, particularly grasses, will germinate under the hay and received protection from the mulch, whilst weed competition is minimised. This would seem to concur with findings of other workers on the response of species with different survival strategies to differing light treatments in terms of germination success (Grime *et al*, 1981). No mulching effect results from the use of seed mixes alone.

Although the hay strewing approach is potentially more labour intensive than the use of seed mixtures (unless big bales are used), it does present opportunities for community involvement and hence hands-on environmental education. The requirement for labour to cut, cart, spread, turn and remove hay during meadow creation using strewn hay allows general ecological principles to be relayed and encourages an appreciation of something which may otherwise have been seen as alien.

One potential problem with using strewn hay during meadow creation is that it may have an adverse effect on the donor meadow. This aspect was not investigated during the present study. Although most grassland species reproduce mainly by vegetative means in a closed meadow sward, germination of seed becomes important when gaps arise. Hay removal whilst still green over consecutive years may result in an imbalance in the seed bank which could ultimately have an effect on community structure. Taking hay from a single source is therefore not recommended as a annual practice; fresh hay is now only removed from Pennerley Meadows every five years.

Of course the use of hay strewing is only applicable where a suitable donor meadow is readily available and as Dawe (in press) points out, this is not the case in some localities. If, however, such meadows are available, amenable owners can provide an invaluable insight into the management techniques which have been used and pass on handy tips based on their own practical experiences.

The successful creation of species-rich grasslands seems to be dependent on several fundamental factors.

The selection of a suitable site, or the suitability of an available site, is one of the first considerations. Basic problems, such as site location and ease of access, are important. The problems resulting from difficult site access, particularly in terms of implementing or maintaining long-term management, have been seen at Peasley Wood (Chapter 3), where despite the availability of suitable cutting machinery, limited access prevented their use on the site. The deterioration of the created sward was the inevitable result.

Access can sometimes be improved - other features of a site are often more difficult to change. The importance of the experimental substrate to successful habitat creation is well documented. Basic ecological principles suggest that extremes of pH are unsuitable for the creation of mesotrophic grasslands in which the species present have evolved to tolerate only mild acidity or alkalinity. Strongly acidic sites are probably more suited to acidic grassland or heathland communities whilst alkaline sites may present opportunities for calcareous grassland creation.

However, it also seems that even minor differences in pH may result in the failure of some desirable species to become established. It was surmised in Chapter 7, that the absence of *Succisa pratensis* in the Valley Park School meadow, despite its abundance in the donor meadow sward, was due to differences in pH between the two sites. It may be possible to manipulate pH by importing materials such as peat, limestone, sulphur or substitutes such as colliery spoil or pulverised fuel ash, although the latter two often have other characteristics which may be limiting to plant growth (Bradshaw & Chadwick, 1980; Dawe, in press; Marrs, in press). It is probably easier to consider pH at an early stage, and reject a potential site for meadow creation if the pH is unsuitable for the desired target community.

Site hydrology is also a critical consideration for meadow creation success, but complex (or even simple) hydrological regimes are very difficult to reproduce. Despite Baines' suggestion that many football pitches may be "frustrated wetland meadows" and that the stress caused by water-logging is easily achievable in public landscapes (Baines 1988), other factors such as water quality, pattern of through flow of water and extent of "water-logging" are all important. It was clear from the experiments at Valley Park School (Chapter 8) and Barnhurst Lane (Chapter 9), that too much water limits the germination of introduced seeds. It may also result in the oxygen supply to developing plants being a limiting factor (Duffey *et al*, 1974). On the other hand, too little water would restrict the development of species dependent on wet soil. It is for these reasons that damp grassland creation is considered by the present author to be more problematic than dry grassland creation, and possibly why the general emphasis in grassland creation has been centred on dry grassland communities.

Despite the potential problems of pH and hydrology, soil fertility is seen by many as the primary consideration when it comes to site choice or preparation for meadow creation. Soil fertility therefore needs to be assessed before attempts to establish species-rich grassland swards. Chemical analyses of plant nutrients in soils have severe limitations which have been discussed earlier in this report, and can only be used to give a broad indication of soil nutrient availability. The nature of the vegetation already present is perhaps a more satisfactory indication.

Fertile soils are generally unsuitable for grassland creation. It is clear that some soils can remain fertile long after periods of fertiliser application (Marrs, in press), whilst others may be rich in macro-nutrients even if fertilisers have not been used (Cooke, 1967). Urban soils containing crushed brick rubble may be rich in potassium and phosphorus but deficient in nitrogen (Bradshaw & Chadwick, 1980) and subsequent invasions of nitrogen-fixing species can render the soil fertile and unsuitable for meadow creation. Increases in organic nitrogen contents and mineralisation rates, presumed to be partly a result of nitrogen-fixing legumes, have also been noted in abandoned arable soils where phosphorus and potassium were not limiting (Marrs & Gough, 1990; Marrs, in press).

Approaches to reducing soil fertility have been investigated during the present study. Marrs (in press) suggests that nutrient supply can be reduced either by increasing nutrient losses, or by manipulating the stores and fluxes within the ecosystem. He suggests that these two approaches translate into two practical strategies:

a) a direct approach, where there is deliberate management to deplete the nutrient supply by maximising crop offtake, and

b) an indirect approach where excess plant-available nutrients are either accumulated in unavailable stores or lost from the soil, for example by encouraging leaching.

Elements of both strategies were used during the experiments at Merridale School (Chapter 5), Compton Agricultural Unit (Chapter 6), Valley Park School (Chapter 8) and Barnhurst Lane (Chapter 9).

Cropping proved to be a valuable approach to reducing soil fertility, although it is recognised that on very fertile soils this may be necessary for several consecutive years for benefits to be seen. However, it has been shown in Chapters 5 and 6 that cropping for just a single season can have benefits in terms of sward establishment and diversity, even if there are no noticeable changes in the chemical properties of the soil measured using conventional analyses. Some crops have proved to be better than others, but early crops, such as spring barley or some varieties of potatoes, can be grown and harvested in the same year as meadow seeding with beneficial results.

Other direct approaches to lowering soil fertility have been attempted. The instant removal of the nutrient pool incorporated in the soil surface layers can be accomplished by turf stripping or top-soil removal, although experiments carried out during the present study have shown that, in some circumstances, these techniques may not enhance sward establishment significantly. In combination with other techniques, such as cropping, they may prove useful, but caution is needed on low-lying sites to prevent the ground level from being lowered to such an extent that water-logging becomes a problem.

At Compton (Chapter 6) and Valley Park School (Chapter 8) these direct approaches were tested against leaching, which Marrs (in press) considers to be an indirect approach to soil fertility reduction. At Compton, a single season of cropping with certain crops was considered to be more effective than reliance on leaching although at Valley Park School there was little apparent difference between plots which had been cropped, turf stripped or left fallow. Turf stripping appeared to be ineffective at removing significant amounts of macro-nutrients from the soil, possible due to the limited amounts of topsoil removed, whilst cropping with maize proved inappropriate due to its difficult establishment and requirement for a long growing season.

In general, manipulation of soil conditions is complicated and difficult and is probably only advisable if no alternative sites, or habitats to create, are available. Grassland creation is probably best avoided altogether on very fertile sites; more productive systems like coppice woodland may be a better choice.

Soil characteristics such as fertility are only one consideration during site preparation. On infertile sites, approaches for preparing suitable seed beds to receive introduced seed, have to be chosen with care. Amenity grassland with little ecological interest needs to be removed prior to grassland creation. Killing the sward with herbicide is an effective approach although it does raise certain ethical questions. Baines (1988) points out that certain European cities have banned the use of herbicides in the public landscape due to public pressure.

The use of herbicides has draw-backs other than its political sensitivity. If done correctly, the killing of an existing grassland sward using herbicide is total, with no chance of certain beneficial species being retained. At Bushbury Hill in Wolverhampton (Chapter 4), herbicide treatment was used during the preparation of one of the meadow plots. However, it became apparent that the dose used had not been adequate with the fortuitous result that *Festuca rubra* was among the surviving species. This plot had a greater abundance of this species, which was also an abundant member of the donor sward, than other plots in which more complete destruction of the existing sward had been achieved. The result was a finer sward which was, in some respects, more similar to the donor than that which became established in the other plots. Had the herbicide treatment been more 'successful', the creation of the grassland in this plot may not have been.

Other approaches to seed bed preparation include various methods of soil cultivation. Ploughing and rotavating, usually followed by harrowing, are effective methods of producing a seed bed, after all farmers use this approach all the time. However, the soil disturbance which results from ploughing or rotavation can release the buried seed of weed species from the seed bank, and in urban soils these are not necessarily the attractive poppies or corn marigolds we sometimes see in corn fields. Persistent perennial weeds, such as docks, are often represented in the seed bank of urban soils. Docks were present in some of the experimental plots in Wolverhampton which had been ploughed or rotavated. Their vigorous growth, and the suppressive effect of the broad spreading leaves, particularly those of *Rumex obtusifolius*, could have easily prevented the establishment of the introduced meadow species and time consuming and expensive contingency measures had to be taken.

Disturbance of soil also causes the release of otherwise unavailable nutrients, through mineralisation of organic material and other mechanisms, thus an elevated soil fertility can result which, as discussed above, can be detrimental in the early stages of grassland establishment. It is clear, therefore, that more intensive site preparation prior to grassland creation does not necessarily result in a more diverse sward and a minimisation of effort may be more appropriate. Taken to its extreme, it was seen at Bushbury Hill experimental plot 4 (Chapter 4) that some species can be successfully introduced to some types of existing grassland provided a source of viable seed is available.

The experiment at Peasley Wood (Chapter 3) demonstrated that, once a created meadow has been seeded, the subsequent management is critical for it development. Grassland management techniques and their importance in maintaining vegetation stability or controlling change are well documented (eg. Duffey *et al*, 1974) and have been discussed earlier. It is well understood that in the absence of management, all grasslands in this country will deteriorate, be it in terms of agricultural quality or nature conservation value.

Grassland management may be clear-cut in theory, and easily implemented in appropriate circumstances such as farmland, but created meadows, particularly in urban areas, present particular problems. Many of the essential elements of grassland management are difficult to implement in towns. Drying hay is an open invitation to fire-raisers. Cattle and other livestock, supposedly grazing the aftermath, could stray or be subject to vandalism. Cutting with the immediate removal of hay, plus subsequent cuts of the aftermath, may therefore be the only option available. However, Trueman *et al* (in press) suggest that traditional hay meadow management, involving both cutting and grazing, may not always be adequately emulated by simple cutting regimes. Alternative forms of disturbance through management may therefore be necessary. Opening up the area for public recreation during autumn and winter months may be effective. Baines (1988) suggests sheep's-foot rollers as a possibility.

The time available for the present study has not allowed detailed studies of varying management and its effect on sward development. However, it is clear that if suitable management is implemented, grassland swards created using strewn hay can continue to diversify as species introduced into the seed bank begin to germinate when conditions become appropriate (cf. *Primula veris* and *Briza media* at Bushbury Hill, Chapter 4)

Habitat creation technology is still in its infancy and the present study hopefully goes some way to contributing to the research being undertaken which will ultimately improve its success and establish its validity. Many areas in which further research is required can be envisaged.

Considering meadow creation in particular, provision for long-term management is frequently inadequate. Very often the actual establishment is seen as the all important aspect of meadow creation and the attitude adopted that if this is successful the rest will follow.

However, management is clearly important for the maintenance grassland diversity. As suggested above, traditional grassland management techniques are often not applicable to new sites, particularly in urban areas. Aftermath grazing, for example, although an essential part of meadow management, is often impossible in urban areas.

Research is therefore required to investigate approaches to simulating traditional meadow management. It has been suggested that chain-harrowing or even disc-harrowing after the main hay cut could be a replacement for the ground disturbance resulting from the trampling of grazing animals although it appears to have remained untested to date.

The hay strewing approach has proved to be a useful method of introducing seed from a range of plant species to new sites. However, its full value has not been fully investigated during the present study. How useful is it, for instance, at introducing invertebrate species associated with the donor meadow?

Some preliminary work carried out on the created meadows in Wolverhampton, comparing them with the donor meadow at Pennerley, have indicated some similarities in the invertebrate fauna (Smith, 1989) and records of moths trapped at Compton Agriculture Unit include a species specific to *Rhinanthus*. *R. minor* was only present at the site after its introduction with the hay from Pennerley Meadows. This obviously is an area in much need of further, more detailed, research.

Other aspects of the hay strewing technique are also in need of investigation and quantification. What, for example, is the optimum ratio of the size of donor meadow to experimental site? or the optimum depth to which hay should be strewn? Investigations are required to determine whether the relative proportion of seed in the hay does reflect the sward composition, and to establish the relationship between flowering time to seed presence in hay.

It is hoped that these questions will, in due course, be answered by further research, some of which is already under way in Wolverhampton.

BIBLIOGRAPHY

Al-Farraj, M.M., Giller, K.E. & Wheeler, B.D. (1984). Phytometric estimation of fertility of waterlogged rich-fen peats using *Epilobium hirsutum* L. *Plant and Soil,* **81,** 283-289.

Allen, S.E., Grimshaw, H.M., Parkinson, J.A.B. & Quarmby, C. (1974). *Chemical Analysis of Ecological Materials.* Blackwell Scientific Publications, Oxford.

Andel, J. van & Bergh, J.P. van den (1987). In: *Disturbance in Grasslands* (Ed: van Andel, J. *et al*). Dr. W. Junk Publishers, Dordrecht.

Anon. (1990). Wild flowers from seed. *Gardening Which,* December 1990.

Ash, H.J., Bennett, R. & Scott, R. (1992). *Flowers in the Grass: Creating and Managing Grasslands with Wild Flowers.* English Nature, Peterborough.

Baines, C. (1988). Flower rich landscapes - problems or opportunities. In: *Wild Flowers '87* (Ed: Taylor, G. & Shildrick, J.). National Turfgrass Council.

Baines, C. (1989). Choices in habitat re-creation. In: *Biological Habitat Reconstruction* (Ed: Buckley, G.P.) pp. 5-8 Belhaven Press, London.

Baines, C. & Smart, J. (1984). *A Guide to Habitat Creation.* Ecology Handbook No. 2. Greater London Council, London.

Bakker, J.P. (1987). Restoration of species-rich grassland after a period of fertilizer application. In: *Disturbance in Grasslands* (Ed: van Andel, J. *et al*). Dr. W. Junk Publishers, Dordrecht.

Bradshaw, A.D. (1969). An Ecologists Viewpoint. In: *Ecological Aspects of the Mineral Nutrition of Plants.* (Eds: Rorison, I.H. & Bradshaw, A.D.) pp. 415-427. Blackwell?.

Bradshaw, A.D. (1983). The reconstruction of ecosystems. *Journal of Applied Ecology*, **20,** 1-17.

Bradshaw, A.D. (1987). Restoration: an acid test for ecology. In: *Restoration Ecology: a Synthetic Approach to Ecological Research* (Eds: Jordan III, W.R., Gilpin, M.E. & Aber, J.D.). Cambridge University Press.

Bradshaw, A.D. & Chadwick, M.J. (1980). *The Restoration of Land.* Blackwell Scientific Publications, Oxford.

Brenchley, W.E. (revised by Warrington, K.) (1958). *The Park Grass Plots at Rothamsted 1856-1949.* Rothamstead Experimental Station, Harpenden.

Brown, (1989). Wild flower seed mixtures supply and demand in the horticulture industry. In: *Biological Habitat Reconstruction* (Ed: Buckley, G.P.) pp. 201-220 Belhaven Press, London.

Buckley, G.P. (Ed) (1989). *Biological Habitat Reconstruction.* Belhaven Press, London.

Burnham, C.P. & Mackney, D. (1964). Soils of Shropshire. *Field Studies*, **2,** 83-109.

Byrne, S. (1990). *Habitat Transplantation in England: A Review of the Extent and Nature of the Practice and Techniques Employed.* England Field Unit Project No. 104, Nature Conservancy Council, Peterborough.

Cavers, P.B. & Harper, J.L. (1964). Biological Flora of the British Isles: *Rumex obtusifolius* L. *Journal of Ecology,* **52,** 737-754.

Champness, S.S. & Morris, K. (1948). The population of buried viable seeds in relation to contrasting pasture and soil types. *Journal of Ecology,* **36,** 149-173.

Chapin III, F.S. (1980). The mineral nutrition of wild plants. *Annual Review of Ecological Systematics,* **11,** 233-260.

Chippendale, H.G. & Milton, W.E.J. (1934). On the viable seed present in soil beneath pastures. *Journal of Ecology,* **22,** 508-531.

Clapham, A.R., Tutin, T.G. & Moore, D.M. (1987). *Flora of the British Isles.* Cambridge University Press.

Cooke, G.W. (1967). *The Control of Soil Fertility.* Lockwood, London.

Dahl, E. & Hadac, E. (1941). Strandgesellschaften der Insel Ostøy im Oslofjord. Eine Pflanzensoziologische Studie. *Nytt Magasin for Naturvidenskapene B,* **82,** 251-312.

Dancer, W.S., Handley, J.F. & Bradshaw, A.D. (1977). Nitrogen accumulation in kaolin mining wastes in Cornwall, Britain. 2: Forage Legumes. *Plant and Soil,* **48,** 303-314.

Dawe, G.F.M. (1984). Urban habitat creation: some points in practice. *Ecos,* **5(4),** 14-19.

Dawe, G.F.M. (in press). *Introduction to Habitat Creation.* Packard Publishing, Chichester.

de Hullu, E. (1985). *Population dynamics of Rhinanthus angustifolius in a succession series.* PhD Thesis, University of Groningen.

Diemont, W.H., Blanckenborg, F.G. & Kampf, H. (1982). *Blij op de Hei? Innovaties in het heidebeheer.* Intern rapport de Werkgroep Verwerking en Afzet van Heideplaggen. Rijksinstituut voor Natuurbeheer, Arnhem.

Digby, G.N. & Kempton, R.A. (1987). *Multivariate Analysis of Ecological Communities.* Chapman & Hall, London.

Duffey, E., Morris, M.G., Sheail, J., Ward, L.K., Wells, D.A. & Wells, T.C.E. (1974). *Grassland Ecology and Wildlife Management.* Chapman & Hall, London.

Dyke, G.V., George, B.T., Johnston, A.E., Poulton, P.R. & Todd, A.D. (1983). The Broadbalk Wheat Experiment 1968-78: Yields and Plant Nutrients in Crops Grown Continuously and in Rotation. *Report of Rothamstead Experimental Station, 1982,* Part 2, 5-44.

Elberse, W.Th., Bergh, J.P. van den & Dirven, J.G.P. (1983). Effects of use and mineral supply on the botanical composition and yield of old grassland on heavy clay soil. *Neth. J. Agric. Science,* **31,** 62-88.

Emery, M. (1986). *Promoting Nature in Cities and Towns: A Practical Guide.* Croom Helm.

Fenner, M. & Spellerberg, I.F. (1987). A feasibility study: enrichment of a neutral grassland. *B.E.S. Bulletin XVIII.*

Fuller, R.M. (1987). The changing extent and conservation interest of lowland grassland in England and Wales: a review of grassland surveys 1930-84. *Biological Conservation,* **40,** 281-300.

Gauch Jr., H.G., Whittaker, R.H. & Wentworth, T.R. (1977). A comparative study of Reciprocal Averaging and other ordination techniques. *Journal of Ecology,* **65,** 157-174.

Gauch Jr., H.G. (1982). *Multivariate Analysis in Community Ecology.* Cambridge University Press.

Gemmell, R.P. (1982). The origin and botanical importance of industrial habitats. In: *Urban Ecology; The Second European Ecological Symposium, Berlin, 8-12 September 1980.* (Eds: Bornkamm, R.; Lee, J.A. & Seaward, M.R.D.). Blackwell.

Gibson, C.C. (1981). *The Host Range and Specificity of the Hemiparasite Rhinanthus minor L.* BSc Thesis, University of York.

Gibson, C.C. (1986). *The Population and Community Biology of Rhinanthus minor L.* PhD Thesis, University of East Anglia.

Gilbert, O.L. (1989). *The Ecology of Urban Habitats.* Chapman & Hall, London.

Gilbert, O.L. & Wathern, P. (1980). The creation of flower-rich swards on mineral workings. *Reclamation Review,* **3,** 217-221.

Gough, M.W. & Marrs, R.H. (1990). A comparison of soil fertility between semi-natural and agricultural plant communities: implications for the creation of species-rich grassland on abandoned agricultural land. *Biological Conservation,* **51,** 83-96.

Graham, D.J. & Hutchings, M.J. (1988). Estimation of the seed bank of a chalk grassland ley established on former arable land. *Journal of Applied Ecology,* **25,** 241-252.

Greenwood, E.F. & Gemmell, R.P. (1978). Derelict industrial land as a habitat for rare plants in S. Lancs. (v.c. 59) and W. Lancs (v.c. 60). *Watsonia,* **12,** 33-40.

Grime, J.P. (1979). *Plant Strategies and Vegetation Processes.* John Wiley & Sons, Chichester.

Grime, J.P., Hodgson, J.G. & Hunt, R. (1988). *Comparative Plant Ecology: A Functional Approach to Common British Species.* Unwin Hyman, London.

Grime, J.P., Mason, G., Curtis, A.V., Rodman, J., Band, S.R., Mowforth, M.A.G., Neal, A.M. & Shaw, S. (1981). A comparitive study of germination characterisitcs in a local flora. *Journal of Ecology,* **69,** 1017-1059.

Grubb, P.J. (1977). The maintenance of species-richness in plant communities: the importance of the regeneration niche. *Biological Review,* **52,** 107-145.

Grubb, P.J., Kelly, D. & Mitchley, J. (1982). The control of relative abundance in communities of herbaceous plants. In: *The Plant Community as a Working Mechanism.* (Ed: Newman, E.I.). Blackwell Scientific Publications.

Hambler, D. (1958). Some taxanomic investigations on the genus *Rhinanthus*. *Watsonia,* **4,** 101-116.

Harper, J.L. (1971). Grazing, fertilizers and pesticides in the management of grasslands. In: *The Scientific Management of Animal and Plant Communities for Conservation.* (Eds. Duffey, E. & Watt, A.S.). Blackwell Scientific Publications.

Harrison, A.F. & Helliwell, D.R. (1979). A bioassay for comparing phosphorus availability in soils. *Journal of Ecology,* **16,** 497-505.

Hart, R.S. & McGuire, W.S. (1963). Effect on clipping on the invasion of pastures by velvetgrass, *Holcus lanatus* L. *Agronomy Journal,* **56,** 187-188.

Hill, M.O. (1973). Reciprocal averaging: an eigenvector method of ordination. *Journal of Ecology,* **61,** 237-249.

Hill, M.O. (1979a). *TWINSPAN - a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes.* Section of Ecology and Systematics, Cornell University, Ithaca, New York.

Hill, M.O. (1979b). *DECORANA - a FORTRAN program for Detrended Correspondence Analysis and Reciprocal Averaging.* Section of of Ecology and Systematics, Cornell University, Ithaca, New York.

Hill, M.O., Bunce, R.G.H. & Shaw, M.W. (1975). Indicator Species Analysis, a divisive polythetic method of classification, and its application to a survey of native pinewoods in Scotland. *Journal of Ecology,* **63,** 237-249.

Hodgson, J.F. (1973). *Aspects of Carbon Nutrition of Angiospermous Parasites.* PhD Thesis, University of Sheffield.

Hopkins, J.J. (1989). Prospects for habitat creation. *Landscape Design,* April 1989.

Hubbard, C.E. (1984). *Grasses.* Penguin Books Ltd., Harmondsworth.

Jefferson, R.G. & Usher, M.B. (1987). The seed bank in soils of disused chalk quarries in the Yorkshire Wolds, England: implications for conservation management. *Biological Conservation,* **42,** 287-302.

Johnston, A.E. & Penny, A. (1972). The Adgell Experiment 1848-1970. *Report Rothamstead Experimental Station 1971, Part 2,* 39-68.

Johnston, A.E. & Poulton, P.R. (1977). Yields on the Exhaustion Land and changes in the NPK content of the soils due to cropping and manuring. *Report Rothamstead Experimental Station 1976, Part 2,* 53-86.

Jones, G.H. (1986). *An Investigation of the Vegetation of an Urban Wetland Conservation Area Affected by Blast-Furnace Slag Tipping and Other Forms of Disturbance.* BSc Thesis, Wolverhampton Polytechnic.

Jones, G.H. (1990). Learning from experience. *Landscape Design,* **193,** September 1990.

Jones, G.H., Trueman, I.C. & Millett, P. (in prep.). The reconstruction of species-rich meadows using freshly cut hay as a seed source.

Jones, L.L. (1967). Studies on hill land in Wales. *Technical Bulletin of the Welsh Plant Breeding Station,* **2,** 1-179.

Jordan III, W.R., Gilpin, M.E. & Aber, J.D. (1987). Restoration ecology: ecological restoration as a technique for basic research. In: *Restoration Ecology: A Synthetic Approach to Ecological Research.* (Eds. Jordan III, W.R., Gilpin, M.E. & Aber, J.D.). Cambridge University Press.

Klapp, E. (1965). *Grünlandvegetation und Standort.* Parey, Berlin.

Lee, J.A. & Greenwood, B. (1976). The colonization by plants of calcareous wastes from the salt and alkali industry in Cheshire, England. *Biological Conservation,* **10,** 131-149.

Londo, G. (1977) *Natuurtuinen en-parken* Thieme, Zutphen.

Mabey, R. (1980). *The Common Ground: A Place for Nature in Britains Future.* Hutchinson/NCC.

Magurran, A.E. (1988). *Ecological Diversity and its Measurement.* Croom Helm.

Malloch, A.J.C. (1988). *VESPAN II: A computer package to handle and analyse multivariate species data and handle and display species distribution data.* University of Lancaster.

Marrs, R.H. (1985). Techniques for reducing soil fertility for nature conservation purposes: a review in relation to research at Roper's Heath, Suffolk, England. *Biological Conservation,* **34,** 307-332.

Marrs, R.H. (in prep). *Soil Fertility and Nature Conservation in Europe: Theoretical Considerations and Practical Management Solutions.* ITE, Monkswood.

Marrs, R.H., Gough, M.W. & Griffiths, M. (1991). Soil chemistry and leaching losses of nutrients from semi-natural grassland and arable soils on three contrasting parent materials. *Biological Conservation,* **57,** 257-271.

Marrs, R.H. & Gough, M.W. (1989). Soil fertility - a potential problem for habitat restoration. In: *Biological Habitat Reconstruction* (Ed: Buckley, G.P.) pp. 29-44. Belhaven Press, London.

Marrs, R.H. & Proctor, J. (1979). Vegetation and soil studies of the enclosed heathlands of the Lizard Peninsula, Cornwall. *Vegetatio,* **41,** 121-128.

Marrs, R.H., Roberts, R.D., Skeffington, R.A. & Bradshaw, A.D. (1983). Nitrogen and the developement of ecosystems. In: *Nitrogen as an Ecological Factor.* (Eds: Lee, J.A., McNeill, S. & Rorison, I.H.). 22nd Symposium of the British Ecological Society. Blackwell Scientific Publications.

Melman, Th.C.P., Clausman, P.H.M.A. & Haas, H.A. Udo de (1985). *Voedselrijkdom indicatie van graslanden.* Mededeling 19. Centrum voor Milieukunde Leiden, Leiden.

Miles, J. (1974a). Experimental establishment of new species from seed in a *Callunetun* in north east Scotland. *Journal of Ecology,* **62,** 527-551.

Miles, J. (1974b). Effects of experimental interference with stand structure on establishment of seedlings in *Callunetum.* *Journal of Ecology,* **62,** 675-687.

Ministry of Agriculture, Fisherise and Food (1985). *Forage Maize.* Booklet 2380, MAFF.

Ministry of Agriculture, Fisherise and Food (1986). *The analysis of agricultural materials.* Reference Book 427. HMSO, London.

Ministry of Agriculture, Fisheries and Food (1988). *Breckland Environmentally Sensitive Area: Guidelines for Farmers.* MAFF, London.

Noy-Meir, I. (1973). Divisive polythetic classification of vegetation data by optimized division of ordination components. *Journal of Ecology,* **61,** 753-760.

Olff, H. & Bakker, J.P. (1991). Long-term dynamics of standing crop and species composition after the cessation of fertilizer application to mown grassland. *Journal of Apllied Ecology,* **28,** 1040-1052.

Page, M.L. (1980). *A Phytosociological Classification of British Neutral Grasslands.* PhD Thesis, University of Exeter.

Parr, T.W. (1986). *Mathematical Models of Grassland.* ITE, Huntingdon.

Petgel, D.M. (1987). Soil fertility and the composition of semi-natural grassland. In: *Disturbance in Grasslands.* (Eds. Andel, J. van *et al*). Dr. W. Junk Publishers, Dordrecht.

Pielou, E.C. (1984). *The Interpretation of Ecological Data - A Primer on Classification and Ordination.* John Wiley & Sons, New York.

Putwain, P.D. (1988). *Heathland Restoration: A Handbook of Techniques.* British Gas, Southampton.

Ratcliffe, D.A. (Ed) (1977). *A Nature Conservation Review.* Cambridge University Press.

Rawes, M. & Welch, D. (1972). Trials to recreate floristically-rich vegetation by plant introduction in the northern Pennines, England. *Biological Conservation,* **4,** 135-140.

Remison, S.U. (1976). *Root Interactions Among Grass Species.* PhD Thesis, University of Reading.

Ries, R.E., Hofmann, L. & Whitman, W.C. (1980) Potential control and value of seeds in prairie hay for revegetation. *Reclamation Review,* **3,** 149-160.

Roberts, H.A. (1986). Seed persistence in soil and seasonal emergence in plant species from different habitats. *Journal of Applied Ecology,* **23,** 639-656.

Robinson, (1870). *The Wild Garden.* John Murray, London.

Rodwell, J. (1991 *et seq.*). *British Plant Communities.* Cambridge University Press.

Rorison, I.H. (1967). A seedling bioassay of some soils in the Sheffield area. *Journal of Ecology,* **55,** 725-752.

Rorison, I.H. (1971). The use of nutrients in the control of the floristic composition of grassland. In: *The Scientific Management of Animal and Plant Communities for Conservation.* (Eds. Duffey, E. & Watt, A.S.). Blackwell Scientific Publications.

Ruff, A. (1979). *Holland and the Ecological Landscape.* Deanwater Press, Manchester.

Sheail, J. (1979). Documentary evidence of the changes in the use, management and appreciation of the grass-heaths of Brekland. *Journal of Biogeography,* **6,** 277-292.

Sinker, C.A., Packham, J.R., Trueman, I.C., Oswald, P.H., Perring, F.H. & Prestwood, W.V. (1985). *Ecological Flora of the Shropshire Region.* Shropshire Trust for Nature Conservation.

Smith, C. (1989). *The Invertebrate Fauna of Ancient and Recreated Meadows.* BSc Thesis, Manchester Polytechnic.

Smyth, R. (1987). Conservation versus creation. *Ecos,* **8(2)**, 34-37.

Snogerup, B. (1982). Host influence on north west European taxa of Odontites (Scrophulariacea). *Annales Botanici Fennici,* **19**, 17-30.

Soil Survey of Great Britain (1960). *Field Handbook.* HMSO.

Stephens, D. (1988). Flower rich landscapes: habitat creation for butterflies. In: *Wild Flowers '87* (Ed: Taylor, G. & Shildrick, J.). National Turfgrass Council.

Sutherland, W. & Gibson, C. (1988). Habitats to order. *New Scientist,* 28 January 1988.

Tansley, A.G. (1939). *The British Islands and Their Vegetation.* Cambridge University Press.

Thompson, K. & Grime, J.P. (1979). Seasonal variation in the seed banks of herbaceous species in ten contrasting habitats. *Journal of Ecology,* **67**, 893-921.

Thurston, J.M. (1969). The effect of liming and fertilizers on the botanical composition of permanent grassland, and in the yield of hay. In: *Ecological Aspects of the Mineral Nutrition of Plants.* (Eds: Rorison, I.H. & Bradshaw, A.D.) pp3-10. Blackwell?

Trueman, I.C. & Lawley, S. (in prep). Title.

Trueman, I.C., Millett, P., Jones, G.H. & Besenyei, L. (in press). Factors controlling vegetational change in habitat creation schemes.

Vermeer, J.G. & Berendse, F. (1983). The relationship between nutrient availability, shoot biomass and species-richness in grassland and wetland communities. *Vegetatio,* **53**, 121-126.

Wathern, P. & Gilbert, O.L. (1978). Artificial diversification of grasslands with native herbs. *Journal of Environmental Management,* **7**, 29-42.

Watt, T.A. (1978). The biology of *Holcus lanatus* L. (Yorkshire Fog) and its significance in grassland. *Herbage Abstracts,* **48**, 195-204.

Wells, T.C.E. (1979). Habitat Creation with Reference to Grassland. In: *Ecology and Design in Amenity Land Management.* (Eds: Wright, S.E. & Buckley, G.P.). Proceedings of a Conference held at Wye College, April 8-11, 1979, in association with the Recreation Ecology Research Group.

Wells, T.C.E. (1980). Management options for lowland grassland. In: *Amenity Grassland: An Ecological Perspective.* (Eds. Rorison, I.H. & Hunt, R.). pp 175-196. John Wiley & Sons, Chichester.

Wells, T.C.E. (1983). The creation of species-rich grasslands. In: *Conservation in Perspective.* (Eds. Warren, A. & Goldsmith, F.B.). John Wiley & Sons.

Wells, T.C.E. (1986). *Alternative Approaches to Creating Grasslands Using Native Species: Successes and Failures.* 26th Askham Bryan Horticultural Technical Course.

Wells, T.C.E. (1987). The Establishment of Floral Grasslands. *Acta Horticulturae,* **195,** 59-69.

Wells, T.C.E. (1988). Flower rich grasslands: slot-seeding into mature swards. In: *Wild Flowers '87* (Ed: Taylor, G. & Shildrick, J.). National Turfgrass Council.

Wells, T.C.E., Bell, S. & Frost, A. (1981). *Creating Attractive Grasslands Using Native Plant Species.* Nature Conservancy Council, London.

Wells, T.C.E., Cox, R. & Frost, A. (1989). *The Establishment and Management of Wildflower Meadows.* Nature Conservancy Council, Peterborough.

Wells, T.C.E., Frost, A. & Bell, S. (1986). *Wild Flower Grasslands from Crop-grown Seed and Hay-bales.* Nature Conservancy Council, Peterborough.

Wells, T.C.E. & Sheail, J. (1988). The effects of agricultural change on the wildlife interest of lowland grasslands. In: *Environmental Management in Agriculture: European Perspectives.* (Ed. Park, J.R.). Belhaven Press.

Wells, T.C.E., Sheail, J., Ball, D.F. and Ward, L.K. (1976). Ecological studies on the Porton Ranges: relationships between vegetation, soils and land-use history. *Journal of Ecology,* **64,** 589-626.

Welsh, P. (1982). *Shropshire Grasslands: A Botanical Survey of Selected Sites.* England Field Unit Project No. 20. Nature Conservancy Council.

Wheeler, B.D., Shaw, S.C. & Cook, R.E.D. (1992). Phytometric assessment of the fertility of undrained rich-fen soils. *Journal of Applied Ecology,* **29,** 466-475.

Wheeler, B.D. & Giller, K.E. (1982). Species richness of herbaceous fen vegetation in Broadland, Norfolk in relation to the quantity of above-ground plant material. *Journal of Ecology,* **70,** 179-200.

Wheeler, B.D. & Shaw, S.C. (1991). Above-ground crop mass and species richness of the principal types of herbaceous rich-fen vegetation of lowland England and Wales. *Journal of Ecology,* **79,** 285-301.

Willems, J.H. (1980). Observations on north-west European limestones grassland communities, an experimental approach to the study of species diversity and above-ground biomass in chalk grassland. *Proc. K. Ned. Wet Series C,* **83,** 279-306.

Williams, E.D. (1978). *Botanical Composition of the Park Grass Plots at Rothamsted.* Rothamsted Experimental Station, Harpenden.

Willis, A.J. (1963). Braunton Burrows: the effects on the vegetation of the addition of mineral nutrients to the dune soils. *Journal of Ecology,* **51,** 353-374.

Worthington, T.R. & Helliwell, D.R. (1987). Transference of semi-natural grassland and marshland onto newly created landfill. *Biological Conservation,* **41,** 301-311.